THE OHIO JOURNAL OF SCIENCE

VOL. XL NOVEMBER, 1940 No. 6

LIMNOLOGICAL STUDIES OF WESTERN LAKE ERIE

I. PLANKTON AND CERTAIN PHYSICAL-CHEMICAL DATA OF THE BASS ISLANDS REGION, FROM SEPTEMBER, 1938, TO NOVEMBER, 1939

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INTRODUCTION

One phase of the fisheries research program now in effect at the Stone Laboratory is the year-round quantitative study of the basic fish foods in the region of the Bass Islands of Lake Erie, and of the ecological factors affecting the various components of this food. The present paper is the first of a series dealing with this subject and it is concerned primarily with year-round data derived from weekly plankton collections and certain physical and chemical determinations in this vicinity. The region of the Bass Islands, like the rest of the shallow western end of Lake Erie, serves as the spawning and feeding grounds for many fish of commercial value. The specific area selected for study was chosen because of its accessibility from the Stone Laboratory and its suitability for winter work due to the fact that from late December to late March it possesses an ice-cover through which investigations can be conducted safely.

Often the bulk of a given species of fish caught during so-called good years belongs to a single year group, the members of which were hatched several years previously. Annual fluctuations in abundance of a species and the dominance of this species by a single year group, as revealed by analyses of commercial catches in this region, immediately suggest that environmental conditions antecedent to time of maturity of a fish may be of considerable significance. It is conceivable that

an abundance of fertilized eggs may be produced during the spawning period of a species but due to unfavorable physical and chemical conditions of the water, or to the lack of proper planktonic food for the newly hatched young, few mature fish will be produced. Since utilization of plankton by adult or immature fish depends upon its abundance and its availability, a plankton investigation becomes an essential part of this program. Data in this paper are general in nature but nevertheless they furnish a basis for future work.

The writer is indebted to Leonard J. Bodenlos, of this laboratory, for valuable assistance with all phases of this investigation; to Kenneth H. Doan, also of this laboratory, for statistical treatment of certain data; to Professor K. Y. Tang, Department of Electrical Engineering, The Ohio State University, for help with the calibration of the photometer; and to other associates who assisted from time to time.

REGION STUDIED

Three natural divisions exist in Lake Erie: the deep eastern portion (that east of a line connecting the city of Erie and the tip of Long Point) with a maximum depth of 64 meters, the central area (that portion west of Long Point and the city of Erie to a line connecting Point Pelee and the city of Sandusky) with a maximum depth of 24.5 meters, and the shallow western end (the remaining portion of the lake) with a maximum depth of 16 meters (Fig. 1). General limnological surveys of these three divisions have been made; the report dealing with the eastern end has been published by Fish (1929), and a summary report of the investigations of the western end has been published by Wright and Tidd (1933). A report pertaining to the studies of the central area has not been published as yet. The present paper is concerned with only a portion of the western end of Lake Erie, that part in the immediate vicinity of the following islands: South Bass, Middle Bass, North Bass, Rattlesnake, and Green (Fig. 2). This region is referred to in this paper as the Bass Islands Region. Wright and Tidd (1933) studied the entire western end of the lake and divided it into several sections, one being designated as the "Island Section" which included approximately the eastern two thirds of the western end of the lake. The Bass Islands Region should not be confused with the much larger "Island Section"; however, except for size these two divisions are quite similar as will be shown later.

The present investigation was confined to an area, consisting of approximately 1000 acres and uniformly 9 to 10 meters deep, lying between the following islands: South Bass, Middle Bass, Rattlesnake, and Green (Fig. 2). Due to currents and wind action this shallow water is kept in continuous circulation throughout most of the year. During winter an ice-cover is formed in this region and extends various distances depending upon the severeness of the winter. Some winters

result in an ice-cover forming over the entire western end of the lake, while others, like the winter of 1938–39, produce an ice-cover nearly limited to the Bass Islands Region. During this particular winter ice did not form until late December, 1938, and did not exceed two inches in thickness until late January, 1939. It later reached a maximum thickness of eight inches. The ice-cover remained until late March, but several times during this period it broke up and shifted away from the islands for a short time, later returning to produce a continuous ice-cover. Each time the ice broke up wind action produced violent churning of the water resulting in complete circulation and increased turbidity.

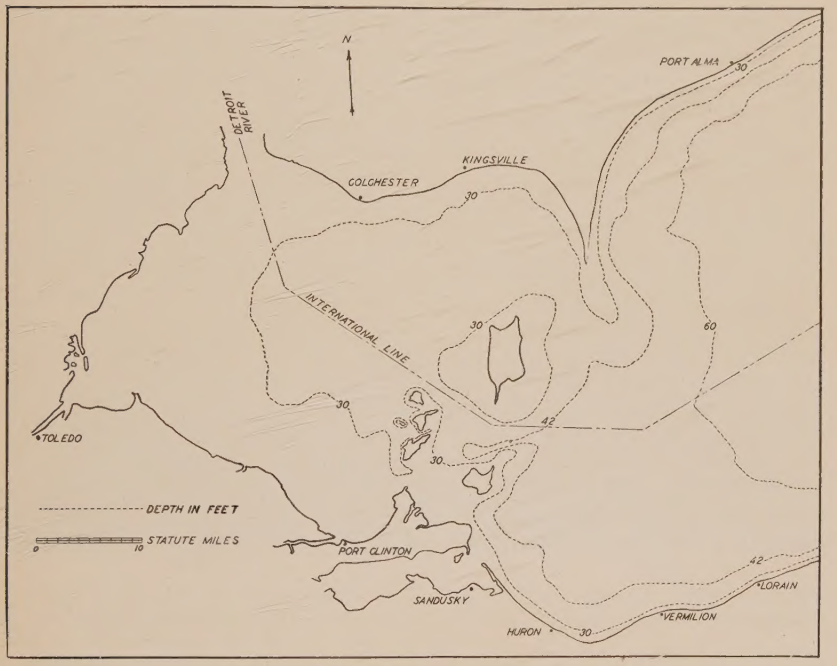


Fig. 1. Map showing the western part of Lake Erie. *Modified from the map of Lake Erie including the waterways between Lakes Ontario and Huron. Published by the U. S. Lake Survey Office June* 2, 1939.

Currents in this area, both surface and sub-surface, are known to exist, but no particular study was made of them. At times of high wind velocities large waves are formed which pound against the steep rocky shores, producing undertow currents of considerable magnitude. Also, these strong winds force the water between the islands setting up currents traveling in various directions. These and the undertow currents produce unpredictable disturbances which may be of considerable importance in respect to plankton distribution. During periods of ice-cover strong currents may be observed to flow in one direction for a few hours, then subside, and later a current will move in the opposite

direction. Hook and line fishermen in this region claim that when the currents are strongest, fishing through the ice is best, irrespective of the direction of flow. This suggests that these currents may be an important factor in the movements of fish in this region.

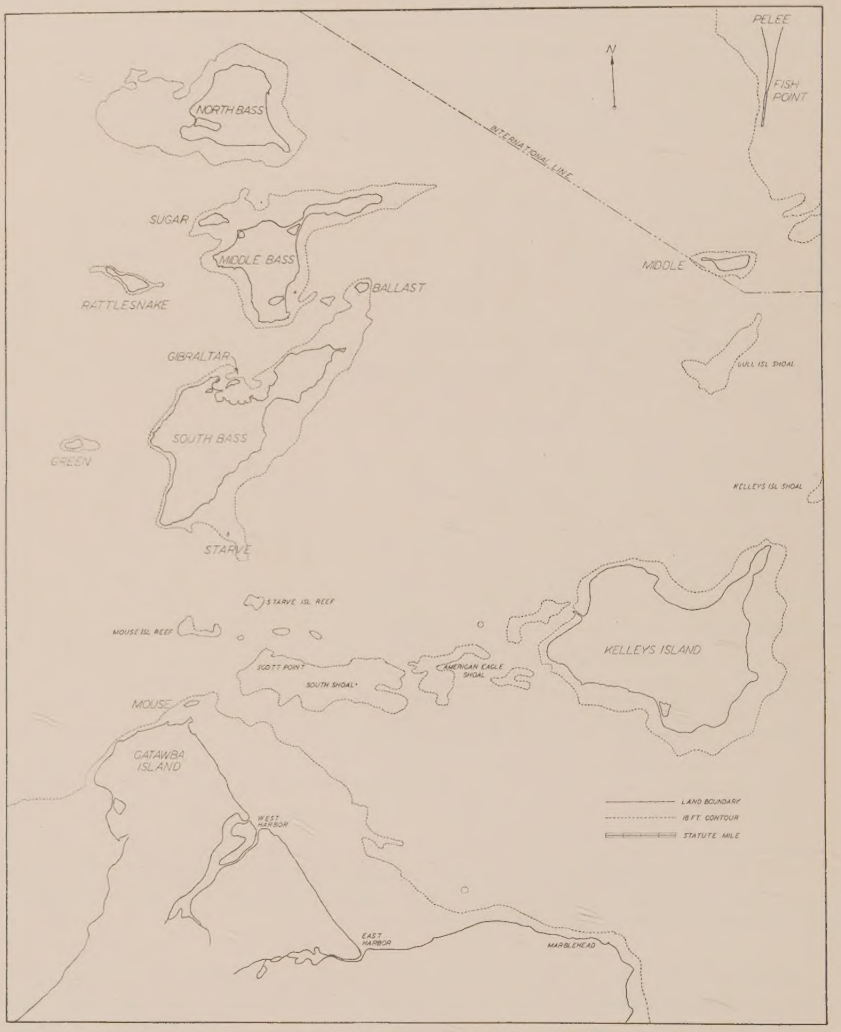


Fig. 2. Map showing the islands and shoals of Lake Erie in the vicinity of Gibraltar Island, on which the Stone Laboratory is located. *Modified from the map of the Islands in Lake Erie including Sandusky Bay, Ohio. Published by the U. S. Lake Survey Office July* 9, 1937.

Bottom sediments in the area studied consist of clay, sand, fine gravel, and organic detritus, appearing in various combinations. Some of these sediments are very compact indicating that they are constantly

swept by currents, while others are soft and apparently free from the influence of currents. These sediments are being studied from the standpoint of organism content, and their mechanical and chemical nature, a report of which will appear at a later date.

METHODS AND EQUIPMENT

During periods of open water all collections were made from a scow (Fig. 5) which was towed to and from collecting stations by a motor boat. On the deck of this scow was mounted a davit equipped with a winch and meter-wheel. A 3-16 inch wire cable was threaded

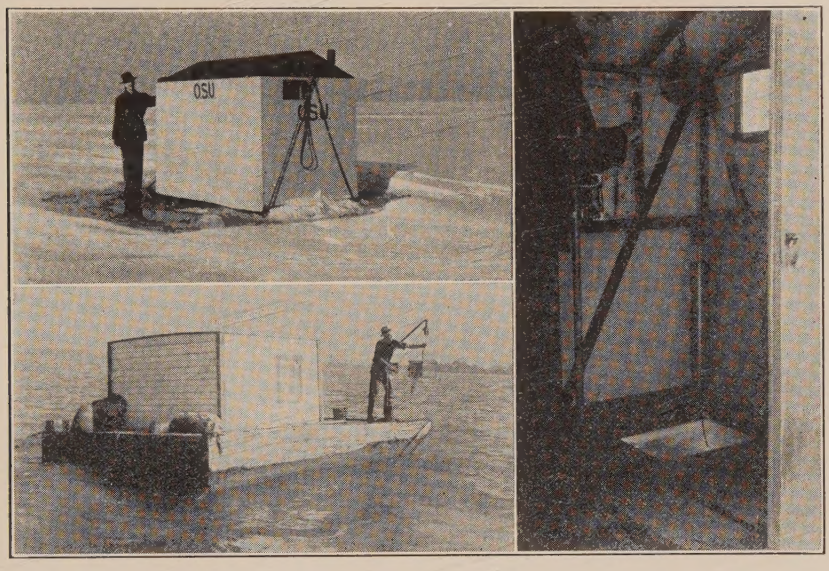


Fig. 3 (upper left). Shanty from which all collections through the ice were made.
Fig. 4 (right). Inside view of shanty showing arrangement of winch and meter-wheel.
Fig. 5 (lower left). Scow from which all open water collections were made.

from the winch through the meter-wheel and was used to raise and lower all equipment. When work was done through an ice-cover the same equipment was mounted in an ice-shanty (Figs. 3 and 4) 8 ft. long, 5 ft. wide, and 6 ft. high. In the floor of the shanty are two holes two feet square which make it possible for two persons to work simultaneously. A small stove installed in one corner keeps the shanty comfortably warm regardless of outside conditions. On two occasions collections were made from this shanty when the air temperature was —5° F. without experiencing any discomfort.

All temperature determinations were made with a Negretti and Zambra reversing thermometer. Temperatures were taken at intervals of 1 meter from the surface to bottom, when surface temperatures varied

more than 2 degrees centigrade from those of the bottom; otherwise, determinations were made at the surface, 5 meters, 9 meters, and bottom. A continuous recording thermograph, recording air and surface water temperatures, was used to supplement field observations during the latter part of the investigation.

Turbidity was determined to the nearest 5 p.p.m. by means of the La Motte turbidity standards when turbidity did not exceed 100 p.p.m. When turbidity exceeded 100 p.p.m. a Jackson turbidimeter was employed.

Transparency was measured by means of a standard Secchi disc, suspended by a chain calibrated in centimeters. The disc was lowered until it disappeared, then raised until it appeared, and the average of the two readings was accepted as the transparency reading. All readings with this disc were made under shaded conditions. Readings through the ice were often made inside the shanty.

Light penetration was measured by means of a Weston photometer mounted in a water tight case, similar to the one described by Atkins, Clarke, etc. (1938). Readings were made of the intensity of total visible illumination in microamperes and milliamperes as recorded by a microammeter. The instrument was calibrated in foot candles and was found not to be sensitive to intensities less than 1.5 foot candles. Readings were made of direct sunlight in air and in water at the following depths: at intervals of 10 centimeters from surface to a depth of 1 meter, at intervals of 0.5 meter from 1 meter to 4 meters, and at intervals of 1 meter from 4 to 10 meters. Data were collected to show the intensity of total visible light at various depths as a percentage of surface light. When an ice-cover was present readings were made through a hole in the ice, either in the shanty or in the open.

Measurements of wind velocity at time of collections were made with a hand anemometer and stop watch. Velocity was expressed in miles per hour.

Water samples for all chemical analyses were collected with a modified Kemmerer water bottle. Hydrogen-ion concentration was determined by the La Motte colorimetric standards. Dissolved oxygen, free carbon dioxide, carbonates, and bicarbonates were determined by methods outlined in the Standard Methods of Water Analysis, 8th edition (1936).

Zooplankton was collected at intervals of 1 meter from surface to bottom by means of a 10 liter plankton trap, equipped with number 25 silk bolting cloth. Samples were preserved immediately with 4 per cent formalin and later were concentrated to 3 cubic centimeters with a pipette covered at the lower end with a double thickness of number 25 silk bolting cloth. The concentrate was placed in a 3 cubic centimeter counting chamber and all zooplankters were enumerated, and expressed in numbers per liter. At times of heavy pulses it was necessary to count only half of the sample and make the proper correction.

Phytoplankton collections were made at surface, at 5 meters, and at 9 meters, by collecting one liter of water with the water bottle. These samples were taken to the laboratory and centrifuged with a Foerst continuous flow centrifuge operating at 20,000 R. P. M. The concen-

trate was transferred from the centrifuge bowl to a vial and was preserved with 4 per cent formalin. Examination of these samples consisted of a qualitative and quantitive enumeration of phytoplankters with a Sedgewick-Rafter cell and a Whipple micrometer. In most cases the concentrate of each sample was diluted to 12.5 cubic centimeters; however, during periods of high turbidity it was necessary to dilute each sample to 25 cubic centimeters. The diluted sample was mixed thoroughly by shaking and then 1 cubic centimeter of it was transferred to the counting cell. All phytoplankters were counted in 10 cubic millimeters in each of two cubic centimeters of concentrate and this number was multiplied by the proper factor, usually 625, to convert to numbers per liter.

Unfortunately, many published phytoplankton data have lost their value through a failure of the investigator to state what units were used in counting various algae. In order that phytoplankton data of this investigation might be compared directly with that obtained by Wright and Tidd (1933) the same units have been adopted. The following have been considered as one unit: one cell of *Navicula*, *Stephanodiscus*, and *Synedra;* one colony of *Coelastrum*, *Coelosphaerium*, *Oöcystis*, and *Pediastrum;* 4 cells of *Scenedesmus;* 5 cells of *Dinobryon;* 8 cells of *Asterionella*, *Crucigenia*, *Diatoma*, and *Tabellaria;* 300 micra of *Melosira*, *Oscillatoria*, *Lyngbya*, *Anabaena*, and *Aphanizomenon;* and 100 micra of *Fragilaria*. Genera not mentioned above, when encountered, were assigned comparable units.

PHYSICAL DATA

TEMPERATURE

Temperature conditions of the water investigated are quite uniform from surface to bottom, due to shallowness and frequent agitation by wind action. Table I shows water temperatures at approximately weekly intervals from Sept. 2, 1938, to Oct. 26, 1939. It will be noted that on a given date temperature did not vary more than 2° C. from surface to bottom during this period, except on three occasions: May 9, May 23, and July 8, 1939. On these three dates thermal stratification was sufficient to form thermoclines. Temperature determinations at intervals of one meter, on May 9, showed that the top of the thermocline was at 5 meters with a temperature of 11.95° C. and the bottom at 8 meters with 9.91° C. No thermocline was detected during the following week, but on May 23 a thermocline reappeared. Temperatures on this date at intervals of one meter from 5 meters to bottom were as follows: 5 meters, 17.4° C.; 6 meters, 16.60° C.; 7 meters, 15.60° C.; 8 meters, 16.80° C.; 9 meters, 12.80° C.; and bottom, 12.60° C. This temperature series shows thermoclines between 6 and 7 meters, and 8 and 9 meters. At 8 meters the water temperature was 1.20° C. warmer than at 7 meters, which indicates that these conditions were temporary and probably due to currents. Again on July 8, a thermocline was found to exist between 5 and 7 meters. No doubt thermoclines existed on other dates than those mentioned, but it seems evident that thermocline formation is an irregular and temporary phenomenon, of little biological significance in this area.

TABLE I. Temperatures in Degrees Centigrade

Depth in Meters	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Nov. 29	Dec. 5	Dec. 15	Dec. 19
0	22.80	21.05	20.65	17.40	18.00	16.80	15.80	17.80	12.30	11.83	12.00	10.80	7.96	7.60	3.10	3.60	1.55	1.00
5	22.80	20.95	20.65	17.30	17.80	16.80	15.80	16.10	12.20	11.81	12.00	10.45	8.00	7.60	3.20	3.60	1.55	1.00
9	22.70	20.80	20.65	17.20	17.80	16.80	15.80	16.00	12.20	11.81	12.00	10.30	8.00	7.60	3.20	3.60	1.55	1.00

Depth in Meters	Jan. 10 1939	Jan. 23	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16	May 23	May 30
0	1.55	0.02	0.03	0.02	0.10	0.02	0.03	0.10	0.90	2.90	3.20	3.65	7.20	8.40	12.03	12.83	17.70	17.40
5		0.02	0.02	0.02	0.10	0.02	0.03	0.10	0.90	2.90	3.10	3.60	6.60	8.10	11.95	12.60	17.40	17.35
9		0.02	0.02	0.02	0.10	0.02	0.03	0.10	0.90	2.90	2.95	3.60	6.57	8.08	9.60	12.60	12.80	17.20

Depth in Meters	June 5 1939	June 14	June 22	June 29	July 8	July 22	Aug. 1	Aug. 11	Aug. 26	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25	Oct. 3	Oct. 9	Oct. 21	Oct. 26
0	20.20	19.20	20.55	22.80	26.70	22.70	25.20	24.20	22.90	23.10	22.80	21.60	21.20	21.20	16.95	18.10	13.05	12.80
5	20.00	19.10	20.35	22.80	25.55	22.60	23.90	23.90	22.80	23.00	22.80	21.60	20.95	19.90	16.90	17.90	13.05	12.20
9	19.20	17.60	19.80	22.70	23.70	22.55	23.75	23.80	22.70	22.90	22.60	21.60	20.90	19.60	16.90	17.75	13.00	12.10

Surface temperature varied from a maximum of 26.7° C. on July 8, 1939, to a minimum of 0.2° C., under the ice-cover, during Jan. and Feb., 1939 (Fig. 8). It will be noted that water temperature for a given date did not vary more than 0.5° C. from top to bottom while the ice-cover existed (Table I). A definite ice-cover existed from Jan. 23 to April 1, 1939, at which time water temperature was less than 1.0° C., but as soon as the ice disappeared the temperature increased rapidly to approximately 3.0° C. and continued to increase until the summer maximum was reached.

TURBIDITY

Water in the Bass Islands Region is characterized by sudden changes in turbidity, ranging from 3 to 140 p.p.m. Turbidity is a factor which appears to have a marked influence upon the productivity of the water investigated. Attention is called to Figure 7, which shows graphically the variations in turbidity, based on weekly determinations from Sep-

TABLE II. Turbidity in p.p.m. For Twelve Consecutive Days During December, 1939

Date	Wind Velocity in m. p. h.	Turbidity in p. p. m.
December 12, 1939.....	10	45
" 13 "	18	70
" 14 "	6	55
" 15 "	6	30
" 16 "	10	20
" 17 "	10	20
" 18 "	3	10
" 19 "	4	10
" 20 "	15	25
" 21 "	20	60
" 22 "	20	70
" 23 "	5	40

tember, 1938, to November, 1939. Unfortunately, the importance of this factor was not realized at the beginning of the investigation; thus, turbidity was determined only once a week and usually on calm days since such days were chosen for general collections. It appears that these data are not truly representative of the average conditions of turbidity, but apparently represent the lower ranges, at least lower than an average based on daily determinations. Daily determinations of turbidity for 12 consecutive days during December, 1939, are recorded in Table 2. These data give a general idea of the degree of variation in turbidity and its relation to wind velocity. Strong winds from the west and northwest, after an extended calm period, may result in a rapid rise in turbidity of 35 p.p.m. or more within 24 hours. When the wind subsides turbidity decreases slowly during the first day due to continued waves and swells resulting from the storm. If several calm days follow in succession a large portion of the suspended material settles out and relatively clear conditions prevail. During the autumn

of 1938 and spring of 1939, there were nearly as many windy days as calm; thus, water in this region was usually quite turbid.

Numerous observations from airplane and motor boat indicate that there is a marked irregularity in distribution of turbid waters in the immediate vicinity of the Bass Islands. Water between Catawba Point and South Bass Island (Fig. 2), known as the South Channel, is often more turbid than water in the area studied. A possible explanation for this fact is that during rainy periods the Portage River, and other rivers along the south shore, discharge highly turbid water into the lake. Some of this water may be carried to various parts of the lake but probably much of it follows along the shore. Often on crossing the South Channel by boat, clear and turbid areas with clearly defined boundaries are encountered, due probably to current action. Likewise, the North Passage, the water between the Canadian shore and the islands, is reported to contain less turbid water than either the South Channel or the Bass Islands Region. This difference is usually attributed to currents which bring in clearer water from the deep eastern end of the lake. It is apparent that the shallow western end of the lake does have highly turbid water most of the year, but it can not yet be stated that certain areas are consistently more turbid than others. It would appear that turbidity was rather uniformly distributed from top to bottom, since turbidity readings at surface, 5 meters, and 9 meters did not show much variation. The lower meter of water was sometimes more turbid than the water above it but usually the difference did not exceed 5 p.p.m.

Microscopic examination of suspended materials causing turbidity reveals fine sand, organic debris, particles of clay, and other sediments. Physical and chemical analyses of these materials are being made at this laboratory for the purpose of determining what role they may play in the cycle of dissolved elements in the water. Also, such a study will aid in tracing the source of sediments responsible for turbidity.

TRANSPARENCY

The maximum Secchi disc reading for the period of investigation was 2.1 meters, February 25, 1939, under the ice-cover; the minimum reading was 0.11 meter on April 5, 1939, shortly after the ice-cover disappeared. Seasonal variation in transparency is shown in Table III, while the averages for the seasons are as follows: September through December, 1938, 0.66 meter; January through March, 1939, 1.3 meters; April through May, 1939, 0.44 meter; June to September, 1939, 1.1 meters; and September to November, 1939, 0.8 meter. Greatest transparency occurred during winter when an ice-cover was present and also during summer months when calm weather prevailed. Lowest transparency existed in spring shortly after the ice disappeared while intermediate conditions prevailed during the autumn months.

Water in the Bass Islands Region is characterized by low transparency, a fact made evident by a comparison of the above data with data derived from investigations of the esatern end of Lake Erie and certain smaller inland lakes. Parameter (1929) reported a maximum Secchi disc reading of 10.5 meters, a minimum 2.0 meters, and an average of 5.0 to 6.0 meters for the eastern end of Lake Erie, from June 15, to September

15, 1928. Average reading for the Bass Island Region for a corresponding period was 1.2 meters. Raymond (1937) who made a year-round study of Bass Lake, Michigan, reported that the Secchi disc readings varied from 4.7 to 5.2 meters, the average being about 5 meters. Tressler (1940) who studied Chautauqua Lake, New York, obtained a maximum

TABLE III. Transparency As Determined By the Secchi Disc

Date	Transparency in Meters	Date	Transparency in Meters	Date	Transparency in Meters
Sept. 2, 1938	0.50	Jan. 10, 1939	1.01	June 5, 1939	1.00
" 7	0.66	" 23	0.84	" 14	0.51
" 16	0.68	Feb. 2	1.40	" 22	0.69
" 23	0.70	" 11	1.17	" 29	1.25
" 28	0.70	" 17	1.87	July 8	1.86
Oct. 5	1.13	" 25	2.15	" 22	1.69
" 12	1.04	Mar. 4	2.00	Aug. 1	1.50
" 17	1.24	" 10	1.92	" 11	0.78
" 26	0.60	" 20	0.92	" 26	1.45
Nov. 1	0.80	" 29	1.08	" 31	1.45
" 5	0.70	Apr. 5	0.11	Sept. 6	1.15
" 10	0.49	" 11	0.13	" 12	0.82
" 17	0.47	" 18	0.40	" 19	0.85
" 22	0.47	" 25	0.25	" 25	1.00
" 29	0.40	May 3	0.50	Oct. 3	0.61
Dec. 5	0.50	" 9	0.46	" 9	1.00
" 15	0.40	" 16	0.80	" 21	0.68
" 19	0.44	" 23	0.85	" 26	0.64
		" 30	1.25		

reading of 5 meters in December, and a minimum of 2.0 meters in August. Many Secchi disc readings higher and lower than those cited above have been reported but these furnish a basis for comparison.

It is realized that determining transparency by means of the Secchi disc is a rough method subject to many errors, but it does give a general idea of transparency and depth of light penetration. Many investigators have used this method alone for determining transparency, and in order to compare this lake with others the same method was used.

When work was begun it was planned to obtain quantitative data in respect to light penetration. The photometer described in the section of this paper under Methods and Equipment was put into operation in September, 1938, at which time it was calibrated. After it had been in use for several months it was again calibrated and was found to be defective. Just when it became defective is not known; consequently, all data collected up to mid-April must be treated only qualitatively. After repair the instrument was recalibrated and put into immediate use obtaining quantitative data. Thus, in this paper, instead of expressing data in terms of total illumination at various depths as a percentage of

TABLE IV. Maximum Depth of Water, in Meters, At Which the Photometer Recorded Illumination

Date	Depth of Light Penetration in Meters	Date	Depth of Light Penetration in Meters	Date	Depth of Light Penetration in Meters
Sept. 2, 1938	5.0	Nov. 17, 1938	4.0	June 29, 1939	6.0
" 7	4.0	" 22	3.0	July 28	9.0
" 16	4.0	Dec. 5	3.0	Aug. 26	9.0
" 23	5.0	" 15	3.0	" 31	9.0
" 28	5.0	" 19	2.5	Sept. 12	3.0
Oct. 5	4.0	Jan. 10, 1939	3.0	" 19	6.0
" 12	6.5	" 23	4.5	" 25	7.0
" 17	6.5	Feb. 11	7.0	Oct. 3	4.0
" 28	4.0	" 17	5.0	" 9	4.5
Nov. 1	4.5	Mar. 4	8.0	" 21	3.0
" 5	4.5	Apr. 5	0.4	" 26	2.5
" 10	4.0	" 11	0.3		

surface light, it has become necessary to state only the greatest depth at which a perceptible light reading could be made with the photometer. The instrument is not sensitive to quantities of light smaller than 1.5 foot candles; therefore, it is assumed that quantities no greater than this existed at depths where no reading could be obtained.

Table IV contains data obtained by the photometer from September, 1938, to November, 1939, expressing in meters the greatest depths at which light was registered by the instrument. According to these data visible light penetrated to a maximum depth of 9.0 meters, a minimum depth of 0.3 meter, and an average depth of 4.7 meters. Average depth

of light penetration for the same periods as discussed for the Secchi disc readings are as follows: September through December, 1938, 4.2 meters; January through March, 1939, 5.5 meters; April, 0.35 meter; June to September, 1939, 8.2 meters; and September to November, 1939, 4.3 meters. In most respects these data correspond closely with those from the Secchi disc readings. Light penetrated to the greatest depths during the time of ice-cover and during the summer months, the least during April, and to intermediate depths from September to November. The effect of an ice-cover on the penetration of daylight into lake water is being investigated, but it will suffice to state here that on several occasions it was found that the ice-cover reflected or absorbed 30 to 50 per cent of the light which fell upon its surface. Until more is known about the influence of an ice-cover on the penetration of daylight into lake water, direct comparisons can not be made between light data obtained through an ice-cover and that obtained in open water.

CHEMICAL DATA

Routine analyses were made at the following depths: surface, 5 meters and 9 meters; however, when marked differences were encountered between these depths additional analyses were made. In general it might be stated that chemical conditions exhibited considerable uniformity from surface to bottom on a given date, but seasonal variations were pronounced. Since vertical distribution of chemical factors is rather uniform it is possible to determine the general chemical conditions by referring to Figure 6, which shows the surface values of each chemical factor investigated.

Dissolved oxygen varied from 5.0 p.p.m. in August and September to 12.9 p.p.m. in March, under the ice-cover (Table V). Variation from surface to bottom did not exceed 2.0 p.p.m. and often it was nearly uniform. Oxygen content of the water was consistently greater during the autumn of 1939, than during the autumn of 1938, which fact can not be explained on the basis of temperature differences (Table I). On several occasions dissolved oxygen showed sudden increases and decreases in content within a period of one week which seems to be related to abundance of organic material in the water, either in the form of plankton or detritus.

Hydrogen-ion concentration (Table VI) varied from 7.5 to 8.4 with the maximum occurring from July to October and the minimum from November to April. From June 14 to 29, the pH was lower than the week preceding or following this period. Irregularities in respect to Ph-th alkalinity, carbon dioxide, and transparency were observed on these same dates. Apparently stormy conditions had stirred up bottom materials, releasing carbon dioxide which brought about the transformation of carbonates into bicarbonates, a lowering of pH, and an increase in turbidity. This one example illustrates how chemical conditions in this region may be altered for short periods by strong winds. No marked variation in vertical distribution of pH was detected despite temporary thermoclines.

TABLE V. Dissolved Oxygen in p. p. m.

Depth in Meters	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Nov. 29	Dec. 5	Dec. 15	Dec. 19
0	5.50	5.12	7.10	6.74	7.60	7.20	7.40	8.46	9.08	6.00	8.60	8.20	8.80	9.71	9.94	12.10	10.60	9.00
5	5.10	5.24	7.22	7.10	8.00	7.46	8.00	7.60	8.68	6.20	8.30	8.06	9.34	9.50	10.56	10.70	10.60	9.76
9	5.00	4.94	7.08	7.66	8.90	7.24	7.20	7.84	8.80	6.00	8.30	7.94	9.36	9.22		10.20	10.50	9.98

Depth in Meters	Jan. 10 1939	Jan. 23	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16	May 23	May 30
0	10.70	11.46	10.20	10.80	12.00	10.80	11.20	10.90	12.94	12.00	11.20	11.80	10.70	10.00	9.94	8.81	9.10	8.70
5		11.56	11.30	11.04	11.24	10.50	11.66	10.72	12.06	12.50	11.94	11.20	10.70	10.40	9.66	8.44	10.60	7.90
9		11.36	11.10	11.36	11.70	12.74	10.06	10.82	12.20	12.54	11.56	11.80	9.80	10.60	9.60	8.96	9.20	7.96

Depth in Meters	June 5 1939	June 14	June 22	June 29	July 8	July 22	Aug. 1	Aug. 11	Aug. 26	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25	Oct. 3	Oct. 9	Oct. 21	Oct. 26
0	8.80	7.70	8.45	7.40	7.50	7.80	7.80	7.60	6.70	5.40	5.60	5.40	8.46	9.00	9.20	10.00	9.80	11.00
5	7.70	9.00	7.45	7.06	7.70	7.60	8.66	6.90	5.80	5.20	5.60	5.40	8.20	8.50	8.40	8.20	9.60	8.10
9	8.14	7.00	7.15	6.34	7.80	6.40	6.86	6.90	6.00	5.34	5.70	7.90	8.14	8.50	8.50	8.20	8.60	8.00

TABLE VI. Hydrogen-ion Concentration

Depth in Meters	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Nov. 29	Dec. 5	Dec. 15	Dec. 19
0	7.9	8.0	8.1	8.1	8.0	8.0	8.0	7.8	7.7	7.7	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6
5	8.0	8.1	8.1	8.1	8.0	8.0	8.0	7.8	7.7	7.7	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6
9	7.9	8.1	8.1	8.1	8.0	8.0	8.0	7.8	7.7	7.7	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6

Depth in Meters	Jan. 10 1939	Jan. 23	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16	May 23	May 30
0	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6	7.6	7.6	7.8	7.8	8.2	8.2
5		7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6	7.6	7.6	7.8	7.8	8.2	8.2
9		7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6	7.6	7 6	7.8	7.8	8.0	8.2

Depth in Meters	June 5 1939	June 14	June 22	June 29	July 8	July 22	Aug. 1	Aug. 11	Aug. 26	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25	Oct. 3	Oct. 9	Oct. 21	Oct. 26
0	8.2	7.8	7.9	8.3	8.4	8.2	8.4	8.2	8.4	8.4	8.4	8.2	8.4	8.4	8.2	8.2	8.2	8.2
5	8.2	7.7	7.8	8.3	8.4	8.2	8.4	8.2	8.4	8.4	8.4	8.2	8.4	8.3	8.2	8.2	8.2	8.2
9	8.2	7.6	7.7	8.2	8.4	8.2	8.2	8.2	8.4	8.4	8.4	8.2	8.2	8.2	8.2	8.2	8.2	8.2

TABLE VII. Free Carbon Dioxide in p. p. m.

Depth in Meters	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Nov. 29	Dec. 5	Dec. 15	Dec. 19
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.11	0.45
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	0.45
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.90	0.45

Depth in Meters	Jan. 10 1939	Jan. 23	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16	May 23	May 30
0	0.40	0.60	0.60	0.60	0.60	0.70	0.60	0 60	0.60	2.90	2.10	0.70	0.90	0.60	0.50	0.0	0.0	0.0
5		0.60	0.60	0.60	0.60	0.70	0.60	0.60	0.60	2.90	2.10	0.70	0.90	0.60	0.50	0.0	0.0	0.0
9		0.60	0.60	0.60	0.60	0.70	0.60	0.60	0.60	2.90	2.10	0.70	0.90	0.70	1.00	0.0	0.0	0.0

Depth in Meters	June 5 1939	June 14	June 22	June 29	July 8	July 22	Aug. 1	Aug. 11	Aug. 26	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25	Oct. 3	Oct. 9	Oct. 21	Oct. 26
0	0.0	0.20	0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.90	0.90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.90	0.90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE VIII. Ph-th Alkalinity in p. p. m.

Depth in Meters	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Nov. 29	Dec. 5	Dec. 15	Dec. 19
0	1.10	1.70	3.40	2.50	2.50	3.90	3.00	3.20	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.90	1.30	2.70	2.20	2.50	3.70	3.20	3.30	0.70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	1.40	1.10	3.20	1.70	2.70	3.80	3.70	3.90	0.80	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0

Depth in Meters	Jan. 10 1939	Jan. 23	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16	May 23	May 30
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.00	0.50
5		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.30	0.50
9		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.50

Depth in Meters	June 5 1939	June 14	June 22	June 29	July 8	July 22	Aug. 1	Aug. 11	Aug. 26	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25	Oct. 3	Oct. 9	Oct. 21	Oct. 26
0	1.00	0.0	0.0	2.00	3.00	1.00	3.00	2.30	2.40	2.50	2.50	4.00	4.40	1.30	0.0	1.00	0.0	0.0
5	1.00	0.0	0.0	1.90	3.00	1.00	3.00	2.30	2.40	2.50	2.00	4.00	4.40	1.30	0.0	1.00	0.0	0.0
9	1.00	0.0	0.0	1.80	3.00	1.00	3.00	2.30	2.50	2.50	2.00	4.00	4.40	1.30	0.0	1.00	0.0	0.0

TABLE IX. Methyl Orange Alkalinity in p. p. m.

Depth in Meters	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Nov. 29	Dec. 5	Dec. 15	Dec. 19
0	95.00	96.90	92.30	92.30	92.40	93.80	94.20	92.70	96.00	93.00	94.50	90.80	92.20	91.70	92.50	90.20	93.40	92.80
5	95.50	96.10	92.00	91.70	92.10	93.40	94.10	92.60	95.50	93.00	93.00	89.80	92.30	92.10	92.50	89.80	93.80	92.40
9	96.00	95.50	91.50	91.30	92.40	92.30	92.70	93.30	93.80	92.50	93.10	90.00	92.40	91.60		90.00	93.90	93.30

Depth in Meters	Jan. 10 1939	Jan. 23	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16	May 23	May 30
0	86.30	85.00	84.60	86.00	84.00	83.20	82.00	82.60	86.00	85.50	84.20	83.30	84.80	83.30	89.80	89.10	93.20	88.20
5		85.00	84.50	84.30	82.00	82.10	83.00	83.40	86.00	85.50	84.20	83.30	85.20	85.70	88.70	87.40	91.80	89.30
9		85.00	84.50	84.20	84.00	83.40	82.00	82.00	86.00	85.50	84.20	87.00	84.80	86.50	87.00	88.80	88.50	91.50

Depth in Meters	June 5 1939	June 14	June 22	June 29	July 8	July 22	Aug. 1	Aug. 11	Aug. 26	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25	Oct. 3	Oct. 9	Oct. 21	Oct. 26
0	92.40	88.30	90.70	89.00	89.20	89.00	92.30	92.20	92.50	92.00	91.50	92.50	91.00	91.00	88.00	88.10	91.30	92.00
5	92.20	91.00	89.20	91.00	90.00	88.00	92.30	92.20	93.00	92.00	92.00	92.50	91.00	91.00	88.00	88.10	91.30	92.00
9	92.00	93.70	91.00	89.00	91.00	88.00	92.30	92.20	93.00	92.00	92.00	92.50	91.00	91.00	88.00	88.10	91.30	92.00

Free carbon dioxide varied from 0.0 to 2.9 p.p.m. from September, 1938, to November, 1939 (Table VII). In general it might be stated that free carbon dioxide was present from December to May and was nearly absent the rest of the year. The maximum carbon dioxide value occurred in April, 1939, during the stormy period which followed the disappearance of the ice-cover. Vertical distribution was almost uniform from surface to bottom for a given date irrespective of season.

Alkalinity of water in the Bass Islands Region (Tables VIII and IX) is due almost entirely to bicarbonates which varied from 96.9 p.p.m. in September, 1938, to 82.0 p.p.m. in March, 1939. In general bicarbonates were present in smaller quantities from January to May than during the rest of the year. Vertical distribution of bicarbonates varied as much as 4.0 p.p.m. from surface to bottom on a given date; however, for the period of investigation it is not possible to state that bicarbonates at one depth were consistently higher or lower than at other depths. Carbonates were absent from September, 1938, to late May, 1939. When present carbonates varied from a minimum of 0.5 p.p.m. in June to a maximum of 4.4 p.p.m. in September.

PLANKTON DATA

PHYTOPLANKTON

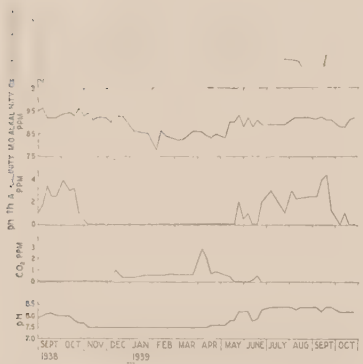
Seasonal Distribution

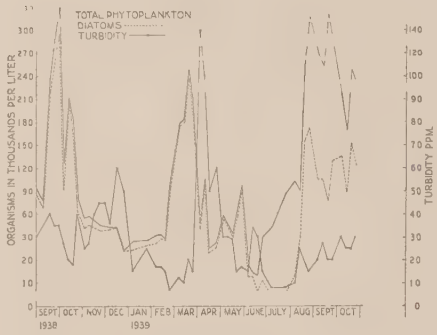
TOTAL PHYTOPLANKTON

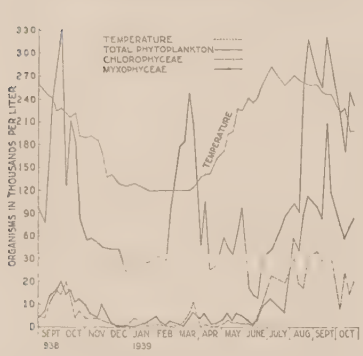
All data pertaining to seasonal distribution and relative abundance of phytoplankton have been derived from an average of collections made from surface, 5 meters, and 9 meters, on a given date. A collection consisted of samples taken from the above depths at one place within the area studied; however, not all collections were made at the same location but were distributed throughout the area from time to time. Nevertheless, all data herein treated have been considered as having come from one station.

General features of seasonal distribution and relative abundance of total phytoplankton are shown in Figure 7 and Table X. It will be noted that definite pulses occurred during the autumn of 1938, and spring of 1939, and again in the autumn of 1939. Pulses of these three periods were approximately of the same size as indicated by the following maxima: autumn of 1938, 330,000 units per liter; spring 1939, 247,000 units per liter; and autumn of 1939, 320,000 units per liter. Duration of the three pulses were as follows: autumn of 1938, 6 weeks; spring of 1939, 8 weeks; and the autumn of 1939, 11 weeks. It should be noted that the entire spring pulse of 1939 occurred under an ice-cover. Fluctuations in quantity of phytoplankton occurred within individual pulses, concerning which no positive explanation can be offered. Data on turbidity (Fig. 7) strongly suggest that many of the fluctuations in quantity of phytoplankters are related to fluctuations in turbidity. However, it is possible that uneven horizontal distribution of phytoplankton within the area may account for these irregularities.

The following list of phytoplankters represents those encountered during quantitative studies, from September 2, 1938, to November 1, 1939. Tiffany (1934) published a qualitative list of plankton algae of this region; thus, the present paper includes only those forms which occurred in sufficient numbers to be considered significant quantitatively. Since identification to species was not practicable in many instances,







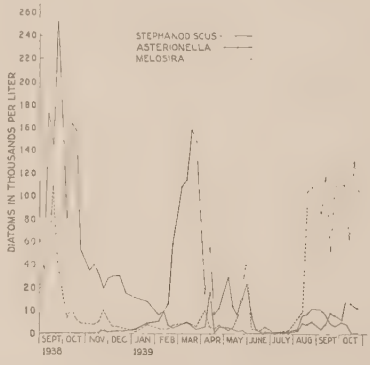


Fig. 6 (upper left). Graphs showing chemical values at the surface for dissolved oxygen, methyl orange alkalinity, Ph-th alkalinity, free carbon dioxide, and pH.

Fig. 7 (upper right). Graphs showing the standing crop of total phytoplankton and total diatoms, in thousands of units per liter, and turbidity in p.p.m.

Fig. 8 (lower left). Graphs showing the standing crop of total phytoplankton, total Chlorophyceae, and total Myxophyceae, in thousands of units per liter, and surface temperature in degrees centigrade.

Fig. 9 (lower right). Graphs showing the standing crop of *Stephanodiscus*, *Asterionella*, and *Melosira*, in thousands of units per liter.

only genus is given. This list consists of 86 algal forms, distributed among the classes as follows: Myxophyceae 17, Chrysophyceae 4, Heterophyceae 2, Bacillariales 23, and Chlorophyceae 40. These forms constituted at least 95 per cent of the total quantity of phytoplankton over the period of investigation. In the following discussion information is given concerning seasonal distribution and relative abundance of the major groups and the more important phytoplankters.

TABLE X. Abundance of Centrifuged Phytoplankton in Thousand, of Units per Liter

Depth in Meters	Group	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Dec. 5	Dec. 15	Dec. 19	Jan. 10 1939
0	Myxophyceae..	4.2	7.0	10.4	17.5	20.3	19.6	16.1	10.6	14.7	12.8	5.0	4.3	9.3	6.8	1.8	0.0	1.2	0.0
	Bacillariales...	87.5	60.4	174.3	266.7	257.6	89.7	185.4	101.6	67.2	31.2	43.4	44.4	30.0	38.9	32.2	31.2	19.3	23.7
	Chlorophyceae	7.0	3.5	9.8	13.3	13.3	19.6	14.0	4.3	4.5	3.2	5.6	4.3	1.2	5.6	3.7	0.0	0.0	4.3
	Miscellaneous.	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total.....	98.7	72.3	194.5	297.5	291.2	128.9	215.5	116.5	86.4	47.2	54.0	53.0	40.5	51.3	37.7	31.2	20.5	28.0
5	Myxophyceae..	2.8	9.1	17.5	12.6	20.3	14.7	12.6	15.0	8.7	6.8	5.0	4.3	9.3	3.7	2.1	0.0	0.0	
	Bacillariales...	82.2	68.2	212.1	255.9	309.4	99.9	180.6	214.6	63.2	46.5	40.6	41.2	34.3	39.0	37.8	53.7	26.2	
	Chlorophyceae	2.8	4.2	7.7	16.1	20.3	25.2	16.1	2.5	7.7	8.1	2.5	3.1	1.2	7.5	0.6	0.0	0.0	
	Miscellaneous.	1.4	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Total.....	89.2	81.5	238.7	284.6	350.0	139.8	209.3	232.1	79.6	61.4	48.1	48.6	44.8	50.2	40.5	53.7	26.2	
9	Myxophyceae..	4.2	4.2	12.6	17.5	18.9	8.4	19.7	7.5	12.6	9.3	8.7	4.3	10.0	6.2	1.5	0.0	0.0	
	Bacillariales...	90.2	72.8	239.4	247.8	320.6	86.2	181.1	186.5	56.1	43.1	53.0	40.3	34.2	31.9	47.2	45.9	25.6	
	Chlorophyceae	3.5	3.5	16.1	18.2	9.8	14.7	10.5	5.6	8.4	1.8	4.3	5.6	7.4	1.8	1.8	0.0	0.0	
	Miscellaneous.	0.0	1.4	8.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Total.....	97.9	81.9	276.5	283.5	349.3	109.3	211.3	199.6	77.1	54.2	66.0	50.2	51.6	39.9	50.5	45.9	25.6	

TABLE X– (*Continued*)

Depth in Meters	Group	Jan. 23 1939	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 20	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16	May 23	May 30
0	Myxophyceae..	2.5	0.6	2.7	0.6	1.8	1.2	0.6	4.3	7.5	2.4	4.1	1.8	1.4	3.1	5.4	5.8	8.9	7.5
	Bacillariales...	27.1	25.1	29.8	29.0	103.3	158.4	176.8	237.7	188.1	39.3	91.6	23.6	27.7	49.4	31.8	33.1	59.1	94.9
	Chlorophyceae	1.2	0.6	0 6	0.0	0.6	1.2	2.5	6.8	15.0	0.0	5.0	0.0	0.0	1.6	4.3	2.6	2.5	1.2
	Miscellaneous.	0.6	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total.....	31.4	26.3	33.7	29.6	105.7	160.8	179.9	248.8	210.6	41.7	100.7	25.4	29.1	54.1	41.5	41.5	70.5	103.6
5	Myxophyceae..	2.5	10.0	2.5	1.8	4.3	2.0	0.6	2.0	4.3	2.4	5.3	1.9	1.8	1.8	8.1	3.0	5.6	2.0
	Bacillariales...	25.6	26.2	30.9	23.4	111.3	195.2	173.1	242.4	190.9	51.2	95.9	24.3	22.5	60.0	26.8	27.4	56.8	85.2
	Chlorophyceae	0.0	1.2	1.8	0.6	0.0	1.8	3.1	5.0	10.0	0.0	0.0	0.0	0.0	1.2	2.5	1.4	2.7	0.6
	Miscellaneous.	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total.....	28.1	38.0	35.2	25.8	115.6	199.0	176.8	249.4	205.2	53.6	101.2	26.2	24.3	63.0	37.4	31.8	65.1	87.8
9	Myxophyceae..	1.2	2.5	1.2	1.2	1.2	1.2	0.0	4.3	7.5	3.7	7.8	1.2	2.0	4.4	3.7	0.8	3.7	6.2
	Bacillariales...	24.7	29.4	28.5	29.0	99.2	173.7	187.9	234.2	185.0	40.3	107.2	22.5	26.2	51.8	41.3	26.8	46.7	86.5
	Chlorophyceae	0.6	1.2	0.6	0.6	0.0	0.0	2.5	5.6	8.7	0.0	0.0	0.6	0.0	1.8	2.5	1.4	0.6	2.6
	Miscellaneous.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total.....	26.5	33.1	30.3	30.8	100.4	174.9	190.4	244.1	201.2	44.0	115.0	24.3	28.2	58.0	47.5	29.0	51.0	95.3

TABLE X—(*Continued*)

Depth in Meters	Group	June 5 1939	June 14	June 22	June 29	July 8	July 22	Aug. 1	Aug. 11	Aug. 26	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25	Oct. 3	Oct. 9	Oct. 21	Oct. 26
0	Myxophyceae..	3.1	1.2	2.2	9.0	12.5	65.7	85.3	40.7	179.3	124.6	125.2	102.0	202.3	113.2	106.6	79.6	78.4	97.2
	Bacillariales...	14.1	18.3	5.5	11.5	4.3	9.5	13.6	14.6	57.0	126.5	103.0	132.6	66.6	79.6	120.9	75.5	143.5	108.5
	Chlorophyceae	1.2	1.2	5.6	9.3	21.2	15.9	43.6	18.1	17.7	32.4	65.4	36.5	35.9	31.8	11.8	24.6	35.4	23.5
	Miscellaneous.	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total.....	18.4	20.7	13.3	30.4	38.0	91.1	142.5	73.4	255.1	283.5	293.6	271.1	304.8	224.6	239.3	179.7	257.3	229.2
5	Myxophyceae..	3.7	0.6	3.3	10.6	21.6	42.5	58.4	42.9	56.0	141.9	96.5	67.4	235.7	120.9	67.2	46.2	63.7	84.3
	Bacillariales...	11.3	10.2	4.7	9.5	3.7	2.4	12.3	23.2	180.5	168.9	104.3	145.7	87.2	134.4	142.7	88.8	141.4	111.5
	Chlorophyceae	1.2	0.6	3.7	10.1	19.3	25.2	38.9	19.4	20.0	28.2	20.6	26.5	39.3	33.0	15.3	24.7	16.5	23.0
	Miscellaneous.	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.5	1.8	0.0	0.0	0.0	0.0
	Total.....	16.2	11.4	11.7	30.8	44.6	70.1	109.6	85.5	258.2	339.0	221.4	239.6	362.7	290.1	225.2	159.7	221.6	218.8
9	Myxophyceae..	1.4	1.2	2.5	6.8	13.3	76.9	25.3	38.2	26.5	69.7	74.3	84.9	182.4	114.5	53.1	46.6	83.3	71.3
	Bacillariales...	12.2	9.3	8.7	11.3	5.0	2.6	11.9	44.1	224.0	223.0	112.0	138.0	76.1	175.2	141.3	102.1	160.0	153.3
	Chlorophyceae	2.5	0.6	4.3	10.6	27.5	17.7	12.9	20.2	14.1	37.7	32.2	23.6	34.1	30.0	17.6	23.6	23.6	15.3
	Miscellaneous.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0
	Total.....	16.1	11.1	15.5	28.7	45.8	97.2	50.1	102.5	264.6	330.4	218.5	246.5	294.4	319.7	212.0	172.3	266.9	239.9

MYXOPHYCEAE

This group was relatively unimportant qualitatively and quantitatively during the first 10 months of investigation, but it became very important quantitatively during the summer and autumn of 1939 (Fig. 8). The average number of units in thousands per liter of this group from September 2 to December 5, 1938, was 10.5; from December 5, 1938, to July 22, 1939, 3.0; and from July 22, to November 1, 1939, 87.3. At no time from September, 1938, to late June, 1939, did the members of this group exceed 20,000 units per liter, and only during September and October of this period was there any indication of a pulse. Late summer and early autumn of 1939 were characterized by large numbers of this group, a maximum of 210,000 units per liter occurring in late September. The contrast in quantity of this group during the two autumns again suggests the influence of turbidity on plankton production.

Anabaena sp. Occurred during summer and autumn, in quantities not exceeding 2,000 units per liter.

Aphanizomenon flos-aquae (L.) Ralfs, and *Oscillatoria* sp., have been grouped in this study, due to the difficulty of distinguishing one from the other while making the quantitative counts. They were present in most collections and were more numerous than any other members of Myxophyceae. These two forms appeared in quantities varying from 1,000 to 8,000 units per liter from September to December, 1938, with the maximum occurring in September. From January to July, 1939, these forms did not exceed 1,000 units per liter, but a definite pulse began in August and reached a maximum of 104,000 units per liter in late September, 1939.

Aphanocapsa sp. Found in a few collections during August and September, 1939, but never exceeded 2,000 units per liter.

Aphanothece sp. Occurred in the collections of August, 1939, but did not exceed 3,000 units per liter.

Chroococcus limneticus Lemmermann.

Chroococcus turgidus (Kütz.) Näg. No attempt was made to separate *Chroococcus* species in counting. Two peaks of production appeared, October and November, 1938, and July through August, 1939, but they did not exceed 5,000 units per liter.

Coelosphaerium dubium Grunow.

Coelosphaerium naegelianum Unger. No attempt was made to separate these two species in counting. Found during September, 1938, and in July, August, and September, 1939, but in quantities less than 4,000 units per liter.

Gloeotrichia sp. Present in two collections of July, 1939, not exceeding 1,000 units per liter.

Gomphosphaeria lacustris Chodat. Occurred during August and September, 1939, in quantities less than 1,000 units per liter.

Lyngbya sp. Rare.

Merismopedia elegans A. Braun.

Merismopedia glauca (Ehr.) Näg.

Merismopedia tenuissima Lemmermann. Species of *Merismopedia* were not separated in counting. This genus occurred only from Septem-

ber to November, 1938, and from August to late October, 1939. A maximum of 15,000 units per liter occurred in September, 1939.

Microcystis aeruginosa Kütz.

Microcystis flos-aquae (Wittr.) Kirchner. In counting, no attempt was made to separate the different species of *Microcystis*. This genus showed two peaks of production: the first in September, 1938, with a maximum of 7,700 units per liter; the second in August, 1939, with a maximum of 46,000 units per liter. The occurrence of irregular numbers of this genus from week to week explains to a large degree the irregularities of the graph for total Myxophyceae (Fig. 8).

Oscillatoria sp. This form is discussed with *Aphanizomenon*.

Chrysophyceae

Dinobryon divergens Imhof.

Dinobryon sertularia Ehr. No attempt was made to separate the species of *Dinobryon*. This genus occurred during spring and summer of 1939, in quantities not exceeding 2,000 units per liter.

Mallomonas alpina Pascher and Ruttner.

Mallomonas caudata Iwanoff. This genus was found only in June, 1939, and did not exceed 1,000 units per liter.

Heterophyceae

Botryococcus sp. Found in quantities not exceeding 1,000 units per liter from May to October, 1939.

Tribonema sp. Occurred from July to October, 1939, but did not exceed 800 units per liter.

Bacillariales

The following statements summarize the general features of this group (Fig. 7): (1) Diatoms were always present and usually constituted the major portion of each collection. (2) Total diatoms exhibited definite pulses during the autumn of 1938, spring 1939, and autumn of 1939. (3) In general diatoms belonging to the order Centrales (*Melosira*, *Cyclotella*, and *Stephanodiscus*) were most numerous in autumn, and those belonging to the order Pennales (*Tabellaria*, *Diatoma*, *Fragilaria*, *Synedra*, and *Asterionella*) were most abundant in spring (Fig. 9). (4) Size and duration of the three diatom pulses were as follows: autumn pulse of 1938, 6 weeks with a maximum of 295,000 units per liter; spring pulse of 1939, 8 weeks with a maximum of 238,000 units per liter; and the autumn of 1939, 11 weeks with a maximum of 175,000 units per liter. A comparison of size and duration of diatom pulses with that of total phytoplankton reveals many similarities (Fig. 7). (5) A winter minimum of 20,000 units per liter occurred in December, 1938, and a summer minimum of 4,000 units per liter occurred in July, 1939. (6) Within each pulse appeared fluctuations in number which apparently are related to fluctuations in turbidity. (7) The spring pulse of 1939 appeared while the ice-cover was present. (8) The maximum of the autumn pulse of 1939 was only 60 per cent of the autumn maximum of 1938. Higher turbidity during the former autumn may be partly responsible for this difference. (9) Average number of diatoms in

thousands of units per liter during pulses and between pulses was as follows: September to November, 1938, 157.7; November, 1938, to March, 1939, 33.5; March to April 18, 1939, 146.8; April 18 to August 25, 1939, 29.0; August 25 to November, 1939, 120.0.

Amphiprora sp. Occurred during spring in quantities less than 1,000 units per liter.

Asterionella sp. During the 14 months of investigation this form showed only one pulse which occurred during February, March, and April, 1939, with a maximum of 158,000 units per liter in March (Fig. 9). During the autumn of 1938, it was nearly absent and in the autumn of 1939 it did not exceed 16,000 units per liter.

Cocconeis placentula Ehr. Occurred in spring and autumn collections but did not exceed 1,200 units per liter.

Cyclotella sp. Found in quantities less than 1,000 units per liter during the autumn of 1938, but it appeared during the autumn of 1939, with a maximum of 8,000 units per liter.

Cymatopleura elliptica (Bréb.) W. Smith. Rare.

Cymbella sp. Found only during spring of 1939, in quantities less than 1,000 units per liter.

Diatoma sp. Present in quantities not exceeding 1,000 units per liter during the autumn of 1938, and spring of 1939.

Encyonema sp. Found occasionally in spring collections. Rare.

Fragilaria crotonensis Kitton.

Fragilaria sp. In counting, no attempt was made to separate the different species of *Fragilaria*. This genus was present in most collections and appeared in two pulses, one in March, 1939, with a maximum of 12,000 units per liter, and a second in October, 1939, with a maximum of 8,000 units per liter. Nothing comparable to a pulse occurred in the autumn of 1938.

Gomphonema acuminatum Ehr. Found occasionally in autumn collections, but did not exceed 1,000 units per liter.

Gyrosigma sp. Found throughout the year but did not exceed 1,200 units per liter.

Melosira distans (Ehr.) Kütz.

Melosira granulata (Ehr.) Ralfs.

Melosira varians Ag. In counting, no attempt was made to separate the different species of *Melosira*. This genus reached a maximum of 112,000 units per liter during a pulse in September, 1938, and in June, 1939, another pulse appeared with a maximum of 45,000 units per liter, and finally a pulse extending from August to November, 1939, reached a maximum of 132,000 units per liter. During intervals between pulses this genus was nearly absent (Fig. 9).

Navicula sp. Present in most collections but did not exceed 3,000 units per liter.

Nitzschia sp. Rare.

Rhizosolenia eriensis H. L. Smith. Due to its transparent nature accurate counts of this form could not be made. Apparently it was most abundant from February to June, 1939.

Stephanodiscus spp. This genus showed a pulse in the autumn of 1938, with a maximum of 251,000 units per liter (Fig. 9) and was char-

acterized by abrupt increases and decreases throughout its duration. This form constituted approximately 95 per cent of the total phytoplankton during this period. A small pulse appeared in April, 1939, and again in the autumn of 1939; however, neither of these last two pulses exceeded 18,000 units per liter.

Surirella spp. Found during autumn and spring in quantities not exceeding 1,800 units per liter.

Synedra spp. Two peaks of production appeared, one in March, 1939, with maximum of 48,000 units per liter, and a second in August, 1939, with a maximum of 20,000 units per liter. A secondary pulse with a maximum of 12,000 units per liter appeared in late May, 1939, but it existed for only two weeks.

Tabellaria fenestrata (Lyngbya) Kütz.

Tabellaria flocculosa (Roth) Kütz. This genus was apparently absent from the plankton except from January to June, 1939. It showed only one pulse which occurred in early March, 1939, with a maximum of 11,000 units per liter.

Chlorophyceae

This group was relatively unimportant quantitatively throughout the period of investigation except during the summer and autumn of 1939. Qualitatively it was one of the most important groups exceeding all others by at least 16 forms. Data on seasonal distribution of total Chlorophyceae (Fig. 8) show that this group produced a small pulse from September to November, 1938, with a maximum of 20,000 units per liter, and another from June to October, 1939, with a maximum of 39,000 units per liter in September. The average number of units in thousands per liter during pulses and periods between pulses was as follows: September to December, 1938, 11.8; December, 1938, to July, 1939, 2.6; and from July to November, 1939, 24.0. Like Myxophyceae this group was more abundant during the autumn of 1939, than in the autumn of 1938.

Actinastrum gracillimum G. M. Smith.

Actinastrum hantzchii Lagerheim. Species of the genus *Actinastrum* were not separated in counting. These forms occurred only in the autumn collections and never exceeded 6,000 units per liter.

Ankistrodesmus convolutus Corda.

Ankistrodesmus falcatus (Corda) Ralfs.

Ankistrodesmus falcatus var. *spirilliformis* G. S. West. In counting, no attempt was made to separate the different species of *Ankistrodesmus*. This genus occurred in quantities not exceeding 1,600 units per liter in the autumn of 1938, but during February and March, 1939, when the ice-cover was present, it reached a maximum of 10,000 units per liter.

Closteriopsis longissima Lemmermann. Found in quantities less than 1,000 units per liter in summer and autumn.

Closterium spp. Occurred in numbers less than 700 units per liter during spring and summer.

Coelastrum microporum Näg.

Coelastrum sp. This genus appeared in about 50 per cent of the collections and was most abundant during the autumn of 1938, with a

maximum of 1,400 units per liter, and again during the summer and autumn of 1939, with a maximum of 1,000 units per liter.

Cosmarium spp. Occurred irregularly during spring and summer but never exceeded 600 units per liter.

Crucigenia irregularis Wille.

Crucigenia rectangularis (Näg.) Gay. The genus *Crucigenia* occurred only during September and October, 1938, in quantities not exceeding 1,200 units per liter.

Dictyosphaerium spp. Occurred in two pulses, the first from September to November, 1938, with a maximum of 7,000 units per liter, and a second from late June to mid-November, 1939, with a maximum of 32,000 units per liter. It was apparently absent except for these two periods.

Gloeocystis sp. Rare.

Kirchneriella obesa (W. West) Schmidle. Found during spring, summer, and autumn but never in quantities exceeding 2,000 units per liter.

Lagerheimia citiriformis (Snow) G. M. Smith. Occurred during summer and autumn, 1939, in quantities not exceeding 600 units per liter.

Oöcystis borgei Snow.

Oöcystis elliptica W. West.

Oöcystis lacustris Chodat.

Oöcystis submarina Lagerheim. In counting, no attempt was made to separate the different species of *Oöcystis*. This genus appeared during summer and autumn, being most abundant in the autumn, but never exceeding 20,000 units per liter.

Pediastrum boryanum (Turpin) Meneghini.

Pediastrum duplex Meyen.

Pediastrum simplex var. *duodenarium* (Bailey) Rabenhorst.

Pediastrum tetras (Ehr.) Ralfs. In counting, no attempt was made to keep the different species of *Pediastrum* separate. This genus appeared in about 50 per cent of the collections but it did not exceed 5,000 units per liter at anytime. Small pulses occurred during the autumns of 1938 and 1939.

Quadrigula closterioides (Bohlin) Printz.

Quadrigula sp. This genus occurred during the autumns of 1938 and 1939, in quantities not exceeding 700 units per liter.

Scenedesmus acuminatus (Lagerheim) Chodat.

Scenedesmus arcuatus Lemmermann.

Scenedesmus bijuga (Turpin) Lagerheim.

Scenedesmus bijuga var. *flexuosus* (Lemmermann) Collins.

Scenedesmus dimorphus (Turpin) Kütz.

Scenedesmus quadricauda (Turpin) Bréb. In counting, the various species of *Scenedesmus* were not kept separate. This genus occurred in most collections but it never exceeded 3,000 units per liter. It was most abundant during late summer and early autumn.

Schroederia setigera (Schroeder) Lemmermann. Appeared irregularly throughout the year with a pulse occurring from July to September, 1939, with a maximum of 13,000 units per liter.

Selenastrum bibraianum Reinsch. Found only in autumn collections, but did not exceed 1000 units per liter.

Sorastrum spinulosum Näg. Occurred in summer and autumn, with a maximum of 1,600 units per liter.

Sphaerocystis schroeteri Chodat. Rare.

Staurastrum paradoxum Meyen. Rare.

Tetraedron sp. Found during summer months in quantities not exceeding 1,000 units per liter.

Westella botryoides (W. West) de Wildemann.

Westella linearis G. M. Smith. The genus *Westella* appeared in the summer plankton but never exceeded 3,000 units per liter.

Per Cent Composition

Composition and relative abundance of phytoplankton for individual collections, from September, 1938, to October, 1939, are shown in Figure 10. The following is a brief analysis of the seasonal variation in

Fig. 10. Graphs showing per cent composition of phytoplankton and zooplankton for individual collections.

composition of this plankton: (1) Diatoms constituted from 5 to 100 per cent of individual collections and were the predominant forms throughout the period of investigation. (2) Diatoms composed at least 70 per cent of the total phytoplankton from September, 1938, to June 22, 1939, and in many instances during this period they constituted 85 to 100 per cent. (3) From June 22, to August 25, 1939, diatoms composed 5 to 48 per cent of the total phytoplankton. (4) From August 25, to September 25, 1939, diatoms made up 25 to 58 per cent of individual collections. (5) Diatoms were not nearly as important a constituent of the plankton during the autumn of 1939, as during the autumn of 1938. (6) Chlorophyceae made up less than 20 per cent, often less than 10 per cent, of individual collections except during the summer months

when it averaged 40 per cent of each collection. (7) Myxophyceae composed less than 20 per cent of each collection from September, 1938, to June 29, 1939, but from July to October, 1939, it composed from 30 to 70 per cent of each collection. (8) Myxophyceae and Chlorophyceae in contrast to Bacillariales were more important constituents of the plankton during the autumn of 1939, than during the autumn of 1938. (9) The miscellaneous group, all phytoplankters not belonging to Bacillariales, Chlorophyceae, and Myxophyceae, did not constitute more than 2 per cent of any collection.

Horizontal and Vertical Distribution

No attempt has been made to determine the nature of horizontal distribution of the phytoplankton within the area studied. As previously stated all plankton data in this paper have been derived from weekly collections made at various locations within a limited area. The fact that these data show consistent trends in respect to seasonal variation of plankton groups as well as individuals, indicates that within the area studied horizontal distribution is quite uniform. It is realized that until a systematic study of this subject is made it will not be advisable to apply the present data to areas not covered in this study.

Differences in abundance of phytoplankton at different depths, in the area studied, were found; however, these differences were not great and not consistently of the same nature (Table X). Data in Table X show that at times the greatest quantity of phytoplankton occurs at the surface, while at other times it is most abundant at 5 meters, and still at other times it is greatest at 9 meters. Even Myxophyceae which normally appears in greatest abundance at or near the surface of most lakes, was the most abundant in many instances at the 9-meter depth. This irregular vertical distribution seems to prevail during spring and autumn when complete circulation is continuous, but under the ice-cover and during mid-summer when circulation is not so evident there are indications that phytoplankters are more consistent in their vertical distribution (Table X). Since vertical distribution of phytoplankton in the Bass Islands Region is irregular it is believed that an average of collections from the three chosen depths gives adequate data to determine the standing crop for a given date.

Zooplankton

Seasonal Distribution

Total Zooplankton

Most data pertaining to zooplankton have been derived from an average of the collections made at the surface, 5 meters, and 9 meters on a given date. Previous work in this region has shown that this method furnishes reliable data in respect to the standing crop. However, studies based on collections at intervals of 1 meter from surface to bottom are in progress and will furnish information on vertical distribution which is lacking in this paper.

Seasonal trends of the standing crop of total zooplankton is shown in Figure 11. This graph reveals that a pulse occurred during the

autumn of 1938, and extended to mid-December; the spring pulse of 1939 occurred from mid-April to late June; the autumn pulse of 1939 appeared from August to October. The maximum of the autumn pulse of 1938 apparently occurred before this investigation began, but there are reasons for believing that this pulse was similar to that of the autumn of 1939, except that it appeared a few weeks earlier. The spring

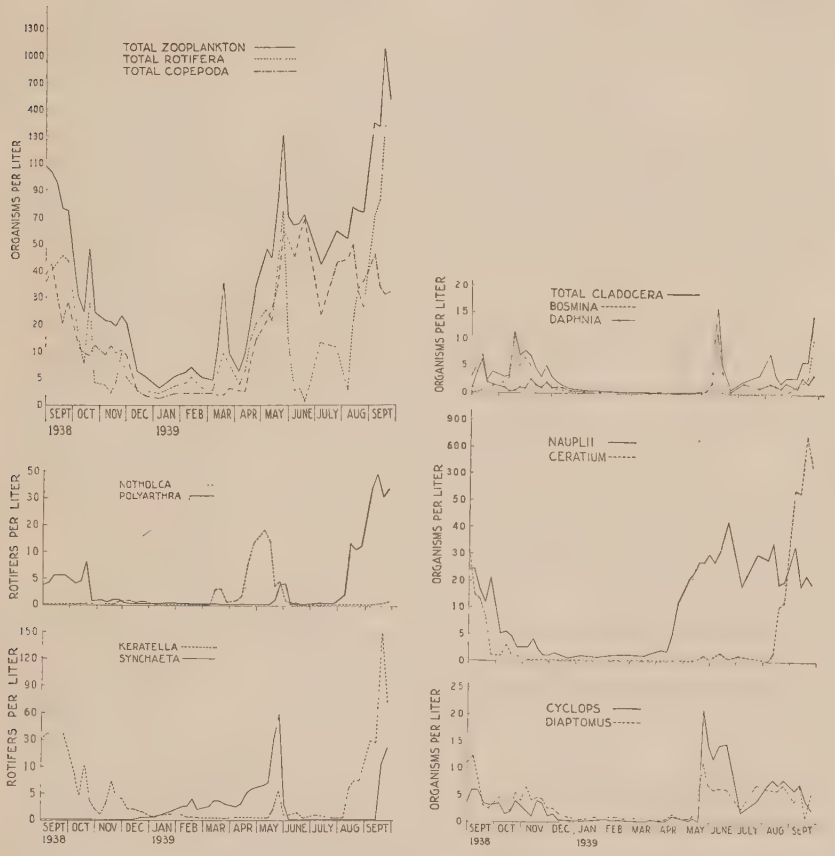


Fig. 11 (upper left). Graphs showing the standing crop of total zooplankton, total Rotifera, and total Copepoda per liter.

Fig. 12 (lower right). Graphs showing the standing crop of *Notholca*, *Polyarthra*, *Keratella*, and *Synchaeta* per liter.

Fig. 13 (right). Graphs showing the standing crop of *Bosmina*, *Daphnia*, Nauplii, *Ceratium*, *Cyclops*, *Diaptomus*, and total Cladocera per liter.

zooplankton pulse of 1939 began at the termination of the spring phytoplankton pulse and reached its peak in late May. Due to the fact that copepods and rotifers did not attain their maxima at the same time, this spring pulse is irregular in appearance and extends over most of three months. Beginning in August the quantity of zooplankton increased gradually until it reached a peak in September. It will be noted that a

marked difference exists between the winter minimum of 3 per liter and the summer minimum of 23 per liter. A large portion of this summer zooplankton was composed of immature stages of copepods (Fig. 13). Many of the abrupt but temporary fluctuations appearing in the graph representing total zooplankton (Fig. 11) are due to sudden increases in quantity of a single genus or even species. Difference in size of spring and autumn pulses of 1939, is due primarily to greater abundance of protozoa during the latter period.

A complete understanding of the nature of seasonal variation of total zooplankton can be obtained only through knowledge of seasonal variation of the constituent plankters. The following section gives the salient features of predominant zooplankters and major zooplankton groups in respect to seasonal abundance. In some instances identification to species was not feasible; thus only genus is given. The list of zooplankters discussed consists of 52 forms, distributed among the major zooplankton groups as follows: Protozoa, 10; Rotifera, 21; Cladocera, 8; and Copepoda, 13.

Protozoa

Members of this group were relatively unimportant qualitatively and only during late summer and early autumn were they important quantitatively. Average number of Protozoa per liter for different times of the year was as follows: September to November, 1938, 8; November, 1938, to March, 1939, 0.0; March to August 25, 1939, 3; August 25, to September 25, 1939, 250. Average for the year was only 33 per liter.

Ceratium hirundinella (O. F. Müller) Schrank. Occurred only in autumn collections (Fig. 13).

Codonella cratera (Leidy). Occurred from June to September, 1939, with a maximum of 66 per liter.

Diffulgia lobostoma Leidy.

Diffulgia sp. This genus appeared irregularly throughout spring, summer, and autumn, especially during periods of violent water agitation. Following a stormy period it appeared in numbers of 400 per liter.

Epistylis sp. Occurred irregularly throughout summer months but did not exceed 10 per liter.

Holosticha sp. Appeared in collections of March, 1939, in numbers of 25 per liter.

Peridinium spp. Found during autumn of 1938, but did not exceed 3 per liter.

Trichophyra epistylidis Claparède and Lachmann. Occurred in the summer of 1939, in numbers not exceeding 8 per liter.

Vorticella sp. Present in most collections, usually attached to diatoms, but did not exceed 15 per liter.

Zoothamnium arbuscula Ehr. Found throughout summer months in quantities not exceeding 12 per liter.

Rotifera

Rotifers were present in all collections and ranked with copepods in abundance. Data on seasonal distribution of total Rotifera (Fig. 11)

show definite pulses during the autumn of 1938, and the spring and autumn of 1939. The autumn pulse of 1938 was irregular in nature and did not exceed a quantity of 45 per liter; the spring pulse reached a maximum of 75 per liter in May, 1939; and the autumn pulse of 1939, reached a peak of 250 per liter in late September. Average number of rotifers per liter during pulses and periods between pulses was as follows: September to November, 1938, 32; November, 1938, to April 18, 1939, 5; April 18, to June 5, 1939, 30; June 5, to August 11, 1939, 5; August 11, to September 25, 1939, 91.

Asplanchna herrickii de Guerne.

Asplanchna priodonta Gosse. This genus occurred in quantities not exceeding 4 per liter during spring and autumn.

Brachionus angularis Gosse. Appeared sporadically throughout the year but most abundant from July to September. Maximum number encountered was 17 per liter.

Chromogaster ovalis (Bergendal). Rare.

Collotheca mutabilis (Hudson). Occurred from July to October with a maximum of 18 per liter in August, 1939.

Colurella sp. Rare.

Conochilus unicornis Rousselet. Found in July and August collections with a maximum of 32 per liter.

Euchlanis sp. Found during spring, summer and autumn, in numbers not exceeding 3 per liter.

Filinia longiseta (Ehr.). Present from April to August but did not exceed 10 per liter.

Gastropus stylifer Imhof. Rare.

Keratella cochlearis (Gosse). Occurred in all collections but appeared in pulses only during the autumns of 1938 and 1939 (Fig. 12). It is one of the most abundant rotifers in this region, exhibiting a maximum of 150 per liter.

Keratella quadrata (Müller). Occurred in winter and spring collections but did not exceed 6 per liter.

Monostyla sp. Found in spring and summer, not exceeding 4 per liter.

Notholca longispina (Kellicott). Found in most collections and produced a pulse during April and May, 1939 (Fig. 12).

Notholca striata (Müller). Found only during March, 1939, in numbers not exceeding 6 per liter.

Ploesoma truncatum (Levander). Occurred in spring and summer collections, but did not exceed 4 per liter.

Polyarthra euryptera Wierzejski.

Polyarthra trigla Ehr. In counting no attempt was made to separate the species of *Polyarthra*. This genus showed a pulse each autumn during September and October and a small pulse during May and June, 1939 (Fig. 12).

Synchaeta sp.

Synchaeta stylata Wierzejski. In counting, no attempt was made to separate the two species of *Synchaeta*. This genus appeared in two pulses, one during April and May, 1939, with a maximum of 70 per liter, and a second during September, 1939, with a maximum of 40 per liter (Fig. 12).

Trichocera longiseta (Schrank). Found in spring collections but did not exceed 5 per liter.

Trichocera sp. (Diurella group). Rare.

Cladocera

Cladocerans were never abundant constituents of the plankton but they did show seasonal variation (Fig. 13). A pulse of cladocerans occurred from September to mid-December, 1938, with a maximum of 12 per liter, but from this time until May, 1939, they were apparently absent from the plankton. A spring pulse, with a maximum of 17 per liter, appeared in June, 1939; a summer pulse with a peak of 8 per liter occurred in August; and the autumn pulse with a maximum of 16 per liter appeared in September, 1939. Irregularity of the graph showing total Cladocera is due to the fact that the 8 species involved had their maxima occurring at different times. The average number of cladocerans per liter during the two pulses was as follows: September to mid-December, 1938, 4.4; May 23, to September 25, 1939, 5.0.

Bosmina longirostris (O. F. Müller). Occurred in the plankton from September through December, 1938, with a maximum of 10 per liter. It appeared in quantities of 2 per liter in June, 1939, and again in August and September, 1939, with a maximum of 10 per liter (Fig. 13). The average number of this species during each autumn pulse was 3 per liter.

Ceriodaphnia reticulata (Jurine). Occurred during July and August, 1939, in numbers not exceeding 3 per liter.

Daphnia longispina (O. F. Müller). Occurred from September to December, 1938, with a maximum of 6 per liter and an average of 2 per liter. A pulse with a maximum of 9 per liter appeared in May and June, 1939, and from July to October, 1939, it was present in numbers not exceeding 3 per liter. The average number per liter from May to October was 3. This species was more abundant than any other cladoceran and had a seasonal distribution similar to that shown for total Cladocera (Fig. 13).

Daphnia pulex (de Geer). Found in quantities not exceeding 3 per liter during spring and summer.

Daphnia retrocurva Forbes. Occurred at about the same time as *D. longispina* but always in numbers less than 4 per liter.

Diaphanosoma leuchtenbergianum Fischer. Occurred from May through September, 1939, with a maximum of 3 per liter.

Leptodora kindtii (Focke). Found from May to September, never exceeding 1 per liter.

Sida crystallina (O. F. Müller). Rare.

Copepoda

General characteristics of seasonal distribution of total copepods are shown in Figure 11. This group was most abundant during autumn and spring at which times pulses appeared. The pulse during the autumn of 1938 probably reached its peak in August before this investigation was begun, although there were 40 per liter present in early September. A spring pulse occurred from early April to mid-July, 1939, with a maximum of 70 per liter in late June. In July the summer minimum of 20

per liter occurred but by August the number had increased to 40 per liter and this level was maintained to mid-September, 1939. It may be noted that the autumn pulse of 1938, and the spring pulse of 1939, were separated by a winter minimum of 2 per liter which existed from mid-December, 1938, to mid-April, 1939. This winter minimum is a sharp contrast, both in size and duration to the summer minimum which separated the spring and autumn pulses of 1939. Immature and adult stages of *Cyclops* and *Diaptomus* made up the bulk of copepod plankton and the following data on average number of these forms during pulses and between pulses will aid in visualizing the relative importance of these forms. Average number of adult *Cyclops* per liter from September through December, 1939, was 3; from January to May 23, 1939, 0.4; from May 23 to October, 1939, 11.0. Average number of *Diaptomus* per liter from September through December, 1938, was 5; from January to May 16, 1939, 0.7; from May 16 to September 25, 1939, 6.0. Average number of nauplii per liter from September to November 17, 1939, was 9; from November 17, 1938, to April 18, 1939, 1; from April 18 to September 25, 1939, 24. It will be seen from these data that nauplii were predominant at all times but especially so from May to October, 1939. Figure 13 shows the general features of seasonal variation of nauplii.

In the following discussion quantitative data are given for all species of copepods except *Diaptomus*. In many instances identification of female *Diaptomus* to species was not attempted; therefore, only general statements are made concerning the members of this genus.

Canthocamptus staphylinoides Pearse. Found in April and May in quantities of 1 per liter.

Cyclops americanus Marsh. Occurred from May to November but did not exceed 3 per liter.

Cyclops bicuspidatus Claus. Found throughout the year but most abundant in May and June, with a maximum of 7 per liter.

Cyclops brevispinosus Herrick. Occurred in most collections but was most abundant from April to September, with a maximum of 6 per liter.

Cyclops leucharti Claus. Occurred in most collections but most numerous from June to September, with a maximum of 6 per liter.

Cyclops prasinus Fischer. Found in collections from April to October, with a maximum of 4 per liter in August.

Diaptomus ashlandi Marsh. Occurred in most collections but was most abundant from May to September.

Diaptomus minutus Lilljeborg. Found from June to September.

Diaptomus oregonensis Lilljeborg. Occurred in most collections, but most numerous from April to September.

Diaptomus sicilis Forbes. Found in most collections but was most abundant in June.

Diapomus siciloides Lilljeborg. Present in collections from September to November, 1938, and during March and August, 1939.

Epischura lacustris Forbes. Occurred from April to October with a maximum of 8 per liter in August.

Limnocalanus macrurus Sars. Found in collections during the months of February and May, in quantities less than 1 per liter.

Per Cent Composition

Composition of individual plankton collections, made from September, 1938, to October, 1939, is shown graphically in Figure 10. In most instances Rotifera and Copepoda composed the greatest percentage of each collection and of these two, Copepoda was the most important component. Protozoa and Cladocera were of secondary importance and ranked about equal in respect to per cent composition. The following is a brief analysis of data pertaining to per cent composition of this plankton. (1) Protozoa in most cases did not constitute more than 20 per cent, usually less than 10 per cent, of total zooplankton from September, 1938, to September, 1939. However, during the month of September, 1939, this group composed from 50 to 70 per cent of the total zooplankton, due to a large pulse of *Ceratium*. (2) Cladocera composed from 10 to 38 per cent of the total zooplankton from early October to mid-December, 1938, but was relatively unimportant the rest of the year except for a few collections during June, July, and August, 1939. (3) Rotifers composed 30 to 85 per cent of the total zooplankton of all collections except those from late October to mid-December, 1938, and from late May to early August, 1939. This group was most important from late December, 1938, to May, 1939. (4) Copepods composed 40 to 60 per cent of the total zooplankton from late October through December, 1938, and 60 to 96 per cent of the zooplankton from late May to mid-August, 1939. Other times of the year this group composed less than 30 per cent of the total zooplankton. (5) Periods during which copepods composed significant percentages of the total zooplankton coincided with similar periods for Cladocera. Rotifers were most abundant in the plankton when Cladocera and Copepoda were least abundant.

Horizontal and Vertical Distribution

During this study little attention was given to the subject of horizontal distribution of zooplankton. The fact that the present data, based on weekly collections, yield rather consistent results in respect to seasonal trends of the zooplankton population indicates that horizontal distribution must be fairly uniform within the area studied. Wright and Tidd (1933) found that plankton Crustacea were not uniformly distributed in the "Island Section," but there was no evidence that they were consistently abundant at certain stations and consistently rare at others.

A limited amount of information pertaining to vertical distribution of zooplankton in the area studied is shown in Table XI. It may be noted that surface collections contained fewer zooplankters than collections from the other depths and the 5 meter-depth contained the largest number of plankters. Rotifera and Protozoa show a very irregular distribution, sometimes appearing in greater numbers at the surface, other times greater at one of the other depths. The Crustacea, however, show the normal distribution in that greater numbers occur at deeper levels during the day. Studies based on diurnal collections made at various times of the year are in progress and will furnish additional data on vertical distribution.

TABLE XI. Abundance of Zooplankton in Numbers per Liter

Depth in Meters	Group	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Dec. 5	Dec. 15	Dec. 19
0	Protozoa...	29.2	10.0	12.0	22.0	0.5	0.7	4.9	0.3	1.0	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0
	Rotifera...	29.3	35.0	45.0	44.0	26.5	8.9	7.8	46.9	4.7	2.9	0.6	5.2	8.9	4.0	2.2	1.9	1.1
	Cladocera..	0.5	2.0	8.0	1.0	1.3	1.0	0.7	1.1	6.3	3.0	7.9	0.9	2.1	1.6	0.2	0.5	0.0
	Copepoda..	31.6	37.0	26.0	19.0	26.0	6.5	7.4	1.8	7.2	5.4	9.8	6.1	7.8	5.8	4.5	1.8	0.9
	Total....	90.6	84.0	91.0	86.0	54.3	17.1	20.8	50.1	19.2	11.7	18.3	12.3	18.8	11.4	6.9	4.2	2.0
5	Protozoa...	40.0	20.0	15.0	2.0	0.6	1.1	2.0	1.2	0.5	0.8	0.0	0.0	0.1	0.1	0.0	0.0	0.0
	Rotifera...	46.0	36.0	39.0	53.0	63.8	15.7	6.9	27.7	4.2	3.8	1.4	4.8	12.1	5.5	4.1	4.8	3.2
	Cladocera..	3.8	5.0	8.0	3.0	4.9	4.1	5.3	21.5	6.5	16.3	6.4	8.2	4.8	3.0	1.0	0.5	0.9
	Copepoda..	46.0	38.0	29.0	21.0	36.6	13.7	10.8	16.4	10.2	12.2	9.4	11.5	12.3	9.8	5.7	2.0	1.6
	Total....	135.8	99.0	91.0	79.0	105.9	34.6	25.0	66.8	21.4	33.1	17.2	24.5	29.3	18.4	10.8	7.3	5.7
9	Protozoa...	25.0	16.0	12.0	2.0	1.5	1.9	2.0	0.8	1.0	0.1	0.0	0.3	0.0	0.0	0.0	0.1	0.0
	Rotifera...	30.0	50.0	45.0	40.0	38.2	19.2	8.1	10.3	3.5	4.1	3.3	3.9	7.7	5.6	5.3	2.0	3.5
	Cladocera..	2.6	7.0	5.0	3.0	2.5	3.5	2.7	9.9	7.5	3.8	7.7	4.5	2.1	10.1	3.9	1.3	0.6
	Copepoda..	37.0	56.0	39.0	18.0	19.6	15.7	10.6	8.4	18.6	9.6	16.9	10.7	10.9	11.7	7.4	4.0	2.0
	Total....	94.6	129.0	101.0	63.0	61.8	40.3	23.4	29.4	30.6	17.6	27.9	19.4	20.7	27.4	16.6	7.4	6.1

TABLE XI. (*Continued*)

Depth in Meters	Group	Jan. 10 1939	Jan. 23	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 20	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16
0	Protozoa...	0.0	0 0	0.1	0.1	0.0	0 0	0.0	0.0	25.0	0.3	0.0	0.3	0.5	0.5	1.5	0 4	5.9
	Rotifera...	1.5	2.1	5.0	4.3	2.5	2.1	3.2	8.1	9.8	2.8	2.8	4.6	10.7	16.0	16.7	13.0	41.2
	Cladocera..	0.0	0.0	0.0	0 0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.3	0.0	0.0	0.2
	Copepoda..	1.6	0.3	1.7	0.5	0.6	2.0	0.2	1.6	1.4	2.0	2.0	3.2	6.0	8.3	13.5	19.0	19.5
	Total....	3.1	2.4	6.8	4.9	3.1	4.2	3.4	9.7	36.2	5.1	4.8	8.3	17.2	25.1	31.7	32.4	66.8
5	Protozoa...	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	27.1	1.8	0.0	1.0	0.5	1.0	1.7	1.6	6.7
	Rotifera...	1.8	4.4	3.2	6.1	5.1	3.2	3.7	10.7	5.7	5.3	4.8	6.5	13.3	16.9	33.0	20.8	51.9
	Cladocera..	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.5
	Copepoda..	1.0	2.8	2.2	3.2	2.3	1.9	2.3	1.3	1.1	3.2	3.1	1.3	8.0	14.2	29.1	40.0	41.9
	Total....	2.9	7.3	5.4	9.4	7.4	5.2	6.0	12.0	33.9	10.3	8.0	8.8	21.8	32.1	63.9	62.4	101.0
9	Protozoa...		0.0	0.0		0.0	0.0	0.0	0.0	25.0	3.0	0.0	0.8	0.3	1.6	1.5	1.6	4.0
	Rotifera...		3.4	3.6		4.9	2.6	1.1	9.5	6.9	4.0	3.2	7.6	14.8	26.5	26.2	30.5	34.2
	Cladocera..		0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.1
	Copepoda..		2.5	3.1		2.7	2.5	3.4	1.7	2.7	3.2	2.3	3.0	9.9	19.7	21.3	16.2	43.5
	Total....		5.9	6.7		7.6	5.1	4.5	11.2	34.6	10.2	5.6	11.4	25.0	47.9	49.1	48.3	81.8

TABLE XI. (*Continued*)

Depth in Meters	Group	May 23 1939	May 30	June 5	June 14	June 22	July 8	July 22	Aug. 1	Aug. 11	Aug. 25	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25
0	Protozoa	5.9	0.3	0.5	3.0	0.3	1.2	0.0	0.0	1.7	17.6	1.2	203.6	148.0	807.2	190.8
	Rotifera	52.9	15.8	3.5	3.8	0.9	4.9	0.4	0.3	18.6	22.6	29.2	114.2	87.4	244.0	205.2
	Cladocera	0.6	1.0	1.6	1.4	0.1	0.3	2.5	0.1	0.7	0.2	0.2	1.8	3.6	3.9	16.2
	Copepoda	25.4	46.8	42.0	45.8	15.9	10.3	47.6	0.7	43.7	19.0	31.0	67.8	24.0	30.4	22.8
	Total	84.8	63.9	47.6	54.0	17.2	16.7	50.5	1.1	64.7	59.4	61.6	387.4	263.0	1085.5	435.0
5	Protoxoa	2.8	0.2	1.0	1.1	0.1	0.8	0.2	0.0	1.4	7.6	15.6	172.0	130.0	690.0	495.0
	Rotifera	125.9	13.2	2.4	1.1	0.5	27.8	32.0	4.9	25.3	39.8	30.8	54.2	89.2	237.6	135.2
	Cladocera	0.9	0.9	37.7	5.9	0.8	2.3	9.0	14.7	5.6	2.8	8.4	2.4	7.6	6.6	13.8
	Copepoda	104.2	52.1	56.0	36.7	39.3	32.9	52.4	92.7	69.9	40.6	42.2	29.8	44.4	33.0	39.6
	Total	233.8	66.4	97.1	44.8	40.7	63.8	93.6	112.3	102.2	90.8	97.0	258.4	271.2	967.2	683.6
9	Protozoa	2.0	0.4	1.0	0.4	0.0	0.3	0.0	0.0	1.3	6.0	9.2	67.6	96.0	980.0	453.0
	Rotifera	45.8	13.4	1.1	3.7	0.8	3.8	1.7	2.6	13.7	34.6	18.4	42.6	71.6	268.8	129.4
	Cladocera	0.4	5.6	8.2	4.6	0.0	4.4	5.3	7.8	6.1	2.0	4.0	4.8	6.4	6.6	15.0
	Copepoda	47.6	59.5	39.2	89.0	155.4	26.8	30.4	39.5	44.7	39.8	34.8	40.8	31.4	29.4	34.8
	Total	95.8	78.9	49.5	97.7	156.2	35.3	37.4	49.9	65.8	82.4	66.4	155.8	205.4	1284.8	632.2

DISCUSSION

Data presented in this paper, derived from a 14 months study of water in the Bass Islands Region of Lake Erie (Fig. 2) resemble in certain respects the data obtained from a general limnological survey of a much larger area, the "Island Section," conducted by the U. S. Bureau of Fisheries and the Ohio Department of Conservation during the spring, summer, and autumn of 1928, 1929, and 1930 (Wright and Tidd, 1933). This similarity suggests that weekly collections made in the Bass Islands Region may give information that is representative of a large portion of the western end of Lake Erie. The following discussion deals with the major features of the Bass Islands Region in respect to plankton and the environmental factors which influence it.

The shallow water of the Bass Islands Region, not exceeding 12 meters in depth, is kept in complete circulation throughout the year except during brief calm periods in spring and summer when conditions are favorable for thermal stratification. Only three times during the investigation was thermal stratification encountered and then it was only temporary in nature, producing little or no effect on the vertical distribution of chemical factors. It might be concluded that this part of Lake Erie resembles a sublittoral zone in respect to thermal and chemical conditions. The primary effect of the ice-cover which existed from January to April, 1939, was that of preventing violent churning of the water by wind. This resulted in lower turbidity even though the water was kept in complete circulation by currents. It is possible that during severe winters an extensive ice-cover may produce conditions different from those observed during the winter of 1938–39, but it appears that under most winter conditions water is kept in complete circulation. The fact that a phytoplankton pulse occurred under the ice-cover indicates that water conditions under the ice were not greatly different from those of the open lake.

Turbidity is believed to be one of the most important physical factors operating in the shallow waters of this area; however, present data do not justify conclusive statements. Examination of Figure 7 gives the impression that phytoplankton pulses occur at times of relatively low turbidity and small phytoplankton populations exist at times of high turbidity. Each phytoplankton pulse, autumn 1938, spring and autumn 1939, occurred when turbidity was relatively low, and periods between pulses were characterized by higher turbidity. Likewise, abrupt decreases and increases in quantity of this plankton during a pulse is seemingly related to fluctuations in turbidity, but a statistical treatment of these data does not yield a significant coefficient of correlation between turbidity and abundance of plankton. If turbidity does affect phytoplankton production it is likely that it is accomplished by influences antecedent to time of collection rather than on date of collection. Thus, it becomes necessary to make daily observations on turbidity and abundance of plankton during spring and autumn when the greatest fluctuations of both occur. Other investigators have reported data similar to that shown in Figure 7. Harris and Silvey (1940) in their work on Texas reservoir lakes found that maxima plankton productions occurred at times of low turbidity in Lake Worth

and Lake Bridgeport but in Lake Dallas and Eagle Mountain Lake maxima plankton productions occurred at times of high turbidity. Daily (1938) studied the phytoplankton of Lake Michigan in the vicinity of Evanston, Illinois, and states, "From weekly studies, it was difficult to ascertain the exact relation between turbidity and plankton pulses; however, the increases in turbidity appear to precede the plankton pulses." The writer believes that a positive correlation does exist between low turbidity and large phytoplankton pulses in this region but this subject awaits further investigation. If turbidity influences abundance of zooplankton it is probably accomplished indirectly through its effect on phytoplankton.

It is conceivable that large quantities of sediment in suspension could injure plankters through mechanical action or by carrying them to the bottom during settling. The writer (Chandler, 1937) observed such effects from studies of lake plankton entering a river. Another evident way by which turbidity can effect phytoplankton production is through reduction of the intensity of illumination at various depths, thus limiting the depth at which photosynthesis can occur. Examination of data on light penetration as determined by the Secchi disc and photometer (Tables III and IV) shows that light was often absent or greatly reduced below depths of 5 meters. Marked variations in depths to which light penetrated occurred daily as well as seasonally, as is indicated by daily turbidity readings (Table II and Fig. 7). The maximum depth to which light penetrated, according to photometer readings, was 9 meters during the summer of 1939, and the minimum was 0.3 meter in April, 1939. An average for the 14 months was 4.7 meters. It appears from these data that light conditions are such that phytoplankters at certain times are able to carry on photosynthesis at all levels from surface to bottom while at other times photosynthetic processes are limited to the upper meter of water. It must be kept in mind that the effect of light on abundance of phytoplankton is due to causes antecedent to time of collection and not at time of collection. High turbidity lasting several days would result in reduced photosynthesis in phytoplankters which would be reflected later in a reduced population. If this application be carried farther it is possible to understand how the degree of turbidity during spring, summer, and autumn might determine the time, duration, and size of phytoplankton pulses.

Unfortunately no information can be offered concerning the qualitative nature of light at various depths in the water of this region. It is known (Birge and Juday 1930, 1931) that turbid waters have a selective effect on transmission of spectral rays. Transmission of short-wave radiations is more affected by suspended materials than transmission of longer wave lengths. It becomes apparent that the effects of turbidity on plankton production can best be approached through a qualitative and quantitative study of light at various depths and the investigation of light requirements of individual plankters for photosynthesis.

Chemical data obtained in this investigation (Tables V–IX) show that chemical conditions vary with the season but differences in vertical distribution from surface to bottom were not significant for a given date.

There are no indications that chemical factors, dealt with in this paper, might have a limiting effect on plankton production. An investigation of dissolved inorganic elements in waters of this area has been carried on simultaneously with this plankton study, and there are indications that some of these elements may be limiting in effect. A discussion of the cycle of dissolved inorganic elements in the waters of this region and their influence on plankton populations will be the subject of another report.

Phytoplankton pulses occurred in the autumn of 1938, and spring and autumn of 1939; however, these three differed from each other in several respects and also from the pulses reported by Wright and Tidd (1933) in the "Island Section." The autumn pulse of 1938 occurred from early September to late October with a maximum of 330,000 units per liter appearing in late September (Fig. 7). This pulse was dominated by diatoms which constituted approximately 80 per cent of the total phytoplankton at this time. *Stephanodiscus* alone composed 75 per cent of the diatoms of this pulse but this form was nearly absent the following autumn. The autumn pulse of 1939 extended from mid-August to mid-October with a maximum of 320,000 units per liter occurring in late September. Diatoms were dominant during this pulse but in contrast to the previous autumn they never composed more than 60 per cent of the total phytoplankton and often less than 50 per cent. Chlorophyceae and especially Myxophyceae contributed much more heavily to this pulse than that of the previous autumn. Turbidity and depth of light penetration (Fig. 7 and Table IV) were very similar during the autumns of 1938 and 1939, especially at the time of phytoplankton pulses, but antecedent to the pulses these factors were different for the two autumns. Average depth to which light penetrated during July and August, 1938, based on four photometer readings, was 3.0 meters while for the same period during 1939 it was 8.0 meters. It would appear that more favorable light conditions of the second year resulted in larger quantities of greens and blue-greens but fewer diatoms. It is quite possible that the different algal forms have different light requirements and that turbidity and depth of light penetration just preceding the pulse influence the abundance of the various groups during the pulse.

The spring pulse of 1939 occurred from late February to early April with a maximum of 247,000 units per liter occurring in late March. Diatoms composed about 90 per cent of this plankton but no one genus was dominant since *Asterionella*, *Fragilaria*, *Synedra*, and *Tabellaria* contributed heavily to this pulse. This entire pulse occurred while an ice-cover was present. Apparently the ice-cover had very little effect on water conditions as reflected by plankton, temperature, and chemical data. Mild winter conditions resulted in a restricted ice-cover limited to the Bass Islands Region, with open water on all sides. This restricted ice field formed a bridge between islands, underneath which the water circulated freely and no doubt mixed with water of the open lake. It might be expected that an ice-cover would reduce turbidity of the water through protection from wind action but during 1939 the water was more turbid during winter than summer. Apparently the turbid water of the open lake mixed to some extent with the ice-covered water. Possibly

the conditions of this particular winter are not typical of winters in general but this study does furnish some interesting data that may be of considerable value when compared with data from other winters. Temperature records during this pulse indicate little change from that of the previous two months and suggest that temperature in itself has little influence on the periodicity of diatoms. Wright and Tidd (1933) reported that the maxima of the spring pulses of 1929 and 1930 occurred in late May and early June. If water temperatures of those years were at all similar to those of a corresponding time in 1939, the plankton pulse must have occurred when the water was 17.0° C. which is 16 degrees higher than when the spring pulse of 1939 occurred.

Wright and Tidd (1933) state that the average abundance of phytoplankton groups, in thousands of units per liter, for the period late May to early October of 1929 and 1930 was as follows: diatoms, 90; greens, 38; blue-greens, 58. Similar data obtained in 1939 for the same period are as follows: diatoms, 76; greens, 20; blue-greens, 63. It is evident that diatoms and greens were more abundant in 1929 and 1930 than for the same period in 1939, while the blue-greens were less abundant. Since the spring pulse of 1939 occurred much earlier than it did in 1929 and 1930 the above data probably are not comparable. To make them comparable the spring pulse of 1939 should be included in the averages. When this is done the average for the diatoms becomes 123 instead of 76, but the other groups are affected very little. It appears from these data that the quality and quantity of phytoplankton in 1929, 1930, and 1939 were quite similar for comparable periods, even though the pulses did not occur at corresponding times.

Zooplankton pulses occurred during the following periods: September to November, 1938; April to July, 1939; and August to October, 1939. No one plankton group dominated all three pulses as is indicated by the following: autumn of 1938, Copepoda and Rotifera contributed about equally; spring of 1939, Rotifera and Copepoda were equally important during the first part of the period while Copepoda was predominant in the latter part; autumn of 1939, Protozoa was dominant. It is apparent that composition of this plankton varies from season to season for the same year and likewise it varies from year to year for corresponding seasons. Phytoplankton and zooplankton pulses appeared at approximately the same time in the autumns of 1938 and 1939, but the phytoplankton pulse, during the spring of 1939, preceded the zooplankton pulse by 6 weeks; however, a secondary phytoplankton pulse occurred along with this zooplankton pulse. Dependence of zooplankton pulses upon phytoplankton pulses is problematical but the two usually occur at about the same time rather than being widely separated as reported here. The spring phytoplankton pulse of 1939 appeared several weeks earlier than it did during the springs of 1929 and 1930; however, the zooplankton pulses for the three years occurred at about the same time (May-June).

A comparison of certain zooplankton data based on a survey of the "Island Section" of Lake Erie (Wright and Tidd, 1933) with that of the present investigation reveals some interesting facts. Wright and Tidd state, "Nothing is known definitely regarding abundance in the months

of December, January, February and March, but there are reasons for believing that crustacea are rare during that period. During the remaining months, the adult crustacea were rare in spring and autumn and were most abundant in summer. In 1930 copepod larvae were most abundant in late spring and probably the same was true in 1929." Data from the Bass Islands Region show that during December, January, February, and March the average number of adult plankton crustacea was 2.0 per liter, which confirms the above statement. However, in this region adult plankton crustacea were most abundant in May and June, and September, while the summer population, though rather large, was smaller than the above periods (Fig. 13). Nauplii were slightly more abundant in spring than in autumn but an almost uniform number with a mean count of 24.0 per liter existed from late April to October, 1939.

The four most abundant genera of plankton Crustacea in the "Island Section" were *Cyclops*, *Diaptomus*, *Daphnia*, and *Diaphanosoma*, and the mean count per liter for each during the period late May to early October, for the years 1929 and 1930, was as follows: *Cyclops*, 10; *Diaptomus*, 6; *Daphnia*, 4; and *Diaphanosoma*, 1. Mean counts of these same genera based on data from the Bass Islands Region for a corresponding period in 1939 are as follows: *Cyclops*, 11; *Diaptomus*, 6; *Daphnia*, 3; and *Diaphanosoma*, 0.5. There is a marked similarity between these two sets of data which suggests that plankton data derived from the Bass Islands Region are representative of the entire "Island Section."

Practically no data on Protozoa and Rotifera were presented in the summary report of the investigation of the "Island Section" by Wright and Tidd, but these groups were found to be numerically important in the plankton of the Bass Islands Region. Rotifera ranked next to Copepoda in per cent composition of total zooplankton, and during winter months it constituted a greater percentage of total zooplankton than any other group. It is quite possible that Wright and Tidd used a coarser meshed net for zooplankton collections than was used during the present investigation, thus allowing many Protozoa and Rotifera to escape. From the standpoint of fish food, Rotifera and Protozoa are relatively unimportant in comparison with Cladocera and Copepoda, but nevertheless these groups must be considered as important constituents of the plankton.

SUMMARY

1. Year-round limnological data based on weekly collections in the region of the Bass Islands, Lake Erie, are presented. Emphasis is placed on seasonal variation of centrifuged phytoplankton, net zooplankton, and certain physical and chemical conditions characteristic of the region.

2. Water, with a maximum depth of 12 meters in this region, circulates from surface to bottom throughout most of the year, due to currents and wind action. This results in

nearly uniform vertical distribution of chemical factors, temperature, turbidity, and phytoplankton.

3. From late December, 1938, to late March, 1939, an ice-cover existed, through which winter collections were made. The ice-cover being confined to this island region apparently formed a bridge between islands, allowing water beneath it to mix freely with water of the open lake.

4. Turbidity is believed to be one of the most important physical factors influencing the productivity of the water in this region. It varied from 3 to 140 p.p.m. and was greatest at times of low plankton production and lowest at times of high plankton production.

5. Maximum depth to which total light penetrated into water varied from 0.3 meter in April to 9 meters during July and August; average for the year was 4.7 meters.

6. Data in this paper suggest that turbidity influences the quality and quantity of light available at various depths for photosynthesis, which in turn may influence the time, duration, and size of phytoplankton pulses.

7. Definite phytoplankton pulses occurred as follows: early September to late October, 1938, with a maximum of 330,000 units per liter; late February to early April, 1939, with a maximum of 247,000 units per liter; mid-August to mid-October, 1939, with a maximum of 320,000 units per liter.

8. Diatoms constituted from 50 to 100 per cent of total phytoplankton except during summer months.

9. Chlorophyceae and Myxophyceae together composed 50 to 90 per cent of the total phytoplankton during June, July, and early August.

10. Composition of phytoplankton differed considerably in the two autumns. In 1938, diatoms constituted from 70 to 90 per cent of the total, while Myxophyceae and Chlorophyecae together composed only 10 to 30 per cent; in 1939, diatoms composed 25 to 55 per cent while Myxophyceae and Chlorophyceae together constituted from 45 to 75 per cent of the total.

11. A phytoplankton pulse with a maximum of 247,000 units per liter occurred under the ice-cover during March, 1939.

12. Zooplankton pulses occurred as follows: September to November, 1938; April to July, 1939; August to October, 1939.

13. Rotifera and Copepoda, about equal in abundance, together composed 40 to 95 per cent of the total zooplankton from September, 1938, to September, 1939. During September, 1939, Protozoa constituted 48 to 72 per cent of the total.

14. Zooplankton and phytoplankton pulses of the two autumns coincided, but the spring phytoplankton pulse terminated before the zooplankton pulse began; a difference of 10 weeks existed between maxima of the two pulses.

15. Physical, chemical, and plankton data of this study resemble in many respects similar data derived from a study of a large portion of the western end of Lake Erie, by Wright and Tidd in spring, summer, and autumn of 1929 and 1930. This suggests that weekly collections in the region of the Bass Islands may supply data that are representative of a large portion of the western end of Lake Erie.

LITERATURE CITED

Atkins, W. R. G., G. L. Clarke, H. Pettersson, H. H. Poole, C. L. Utterback, and **A. Angström.** 1938. Measurement of Submarine Daylight. Jour. du Conseil International pour l'Exploration de la Mer, 13 (1): 37–57.

Birge, E. A., and **C. Juday.** 1930. A Second Report on Solar Radiation and Inland Lakes. Trans. Wis. Acad. Sci., Arts, Let., 25: 285–335.

1931. A Third Report on Solar Radiation and Inland Lakes. Trans. Wis. Acad. Sci., Arts, Let., 26: 383–425.

Chandler, David C. 1937. Fate of Typical Lake Plankton in Streams, Ecol. Monographs, 7: 445–479.

Daily, William Allen. 1938. A Quantitative Study of the Phytoplankton of Lake Michigan Collected in the vicinity of Evanston, Illinois. Butler Univ. Botanical Studies, 4 (6): 65–83.

Fish, J. Charles. 1929. Preliminary Report on the Cooperative Survey of Lake Erie. Bull. Buffalo Soc. Nat. Sci., 14 (3): 1–220.

Harris, Benjamin B., and **J. K. Gwynn Silvey.** 1940. Limnological Investigation on Texas Reservoir Lakes. Ecol. Monographs, 10: 111–143.

Parmenter, Richard. 1929. Hydrography of Lake Erie. Bull. Buffalo Soc. Nat. Sci., 14 (3): 25–50.

Raymond, M. R. 1937. A Limnological Study of the Plankton of a Concretion-Forming Marl Lake. Trans. Amer. Micro. Soc., 56 (4): 405–430.

Standard Methods for the examination of water and sewage, 8th ed. 1936. Amer. Pub. Health Assoc., New York, 309 pp.

Tiffany, Lewis Hanford. 1934. The Plankton Algae of the West End of Lake Erie. Franz Theodore Stone Laboratory, The Ohio State Univ., Contr. 6: 1–113.

Tresseler, Willis L., Laverne G. Wagner, and **Ruby Bere.** 1940. A Limnological Study of Chautauqua Lake. II. Seasonal Variation. Trans. Amer. Micro· Soc., 59 (1): 12–30.

Wright, Stillman. and **Wilbur Tidd.** 1933. Summary of Limnological Investigations in Western Lake Erie in 1929 and 1930. Trans. Amer. Fish. Soc., 63: 271–285.

TOTAL DISTRIBUTION OF TASTE BUDS ON THE TONGUE OF THE PUP[1]

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INTRODUCTION

This paper reports the results of the second of a series of proposed studies from this laboratory on the distribution and innervation of taste buds; the first having been published by Elliott ('37).

A search of the available literature indicated that information on taste buds was limited. As Elliott ('37) has given a brief review of the literature, reference to previous research will be considered in a comparative way in the portion of this paper devoted to the discussion of the present investigation.

I wish to express my appreciation to Dr. Rush Elliott, who directed the problem, for his initial suggestion of this research and for the timely suggestions given during the course of the investigation which saved needless loss of time and waste of material; to Dr. F. H. Krecker for use of laboratory material and equipment; and to Mr. Lawrence Goldberg for the photographic work appearing in this paper.

MATERIALS AND METHODS

The material for this study consists of tongues taken from six pups which varied in age from one to five days. Three of these tongues which were used in the histological work were from five-day old pups of the same litter. These tongues were fixed in 10% formalin for ten days and washed in running water for twenty-four hours. The tongues were dehydrated in a graduated series of ethyl alcohol to 70%.

One tongue was dehydrated and infiltrated by the dioxan method as outlined by Guyer ('36). Difficulty due to hardening was encountered in sectioning the tongue dehydrated by this method. The other two tongues were dehydrated and infiltrated by a modification of the normal butyl alcohol technique described by Lee ('37). These three tongues were sectioned serially at 20 micra. Mallory's triple stain and iron hematoxylin were tried, but a dilute solution of Delafield's hematoxylin proved most satisfactory and was used for nearly all of the sections. Euparal was used for the mounting medium.

By a careful study of several taste buds it was found that all buds appeared in two sections and some appeared in three sections; it seems

[1]From a thesis submitted in partial fulfillment of the requirements for the degree Master of Science in Ohio University.

[2]Contribution No. 17 from the Department of Zoology.

from this that a bud must be nearly forty micra in thickness. A figure to show the total distribution of the taste buds over the dorsum of the tongue was prepared by dividing the tongue into twenty-six divisions. The reasons for using this number of divisions were that the circumvallate papillae of all tongues fell into comparable areas, and the average number of sections in each division was a whole number. A record of the number of taste buds exclusive of the circumvallate papillae was made and a table prepared (Table I) to show the localization in each region.

TABLE I

TABLE OF NUMBER OF TASTE BUDS FOUND IN THE FUNGIFORM PAPILLAE OF THE THREE TONGUES STUDIED

DIVISION	TONGUE 1	TONGUE 2	TONGUE 3	AVERAGE ALL TONGUES
1	13	18	16	16
2	42	33	57	44
3	65	44	81	63
4	62	52	94	69
5	75	34	89	66
6	83	27	91	67
7	80	51	101	77
8	91	33	101	75
9	117	49	89	85
10	90	49	84	74
11	101	58	87	82
12	51	59	77	62
13	53	48	86	62
14	60	70	91	74
15	49	85	93	76
16	66	83	90	80
17	84	101	97	94
18	79	115	89	94
19	84	79	112	92
20	53	42	99	65
21	8	7	44	20
22	10	6	6	7
23	0	0	0	0
24	0	0	0	0
25	0	0	0	0
26	0	0	0	0
Total...	1,416	1,143	1,774	1,444

Each section is 20 micra in thickness. Each division in tongue number 1 represents 76 sections; in tongue number 2, 68 sections; in tongue number 3, 75 sections; average for all tongues, 73 sections.

It was noted that the number and the positions of the circumvallate papillae were not constant in the tongues prepared for histological study. Three more tongues were studied under the macroscopic camera lucida and the positions of the circumvallate papillae plotted. In figure 2 the positions of these papillae in the three tongues used in the histological study are represented by the figures in the top row; the lower row of figures are of those tongues which were used in the macroscopic study only.

Counts of taste buds present in the circumvallate papillae of tongue number 2 were made by use of serial projection photographs at a magnification of 200 diameters.

An outline of a tongue was prepared by projection, measurements being made of every seventy-fifth section of tongue number 3. By use of this outline a figure (Fig. 4) was prepared to show the total distribution of taste buds over the entire dorsum of the tongue. This number was reckoned by taking the average number of taste buds appearing in the fungiform papillae of the three tongues and the total number of taste buds observed in the circumvallate papillae of tongue number 2.

Fig. 1. Photomicrograph of a normal fungiform papilla with two taste buds in its top. × 350.

DISCUSSION

Taste buds are described in textbooks of histology (Bailey, Bremer, Maximow and Bloom, and Piersol) as occurring on various parts of the tongue, on the glossopalatine arch, on both sides of the epiglottis, on the posterior wall of the pharynx down to the inferior edge of the cricoid cartilage, on the soft palate especially in the region of the uvula (Hoffman, 1875), and in the region of the palatine tonsil of the foetus (Ponzo, '07). This paper is restricted to a study of the total distribution of taste buds on the tongue.

On the dorsum of the tongue of the pup, filiform, fungiform, and circumvallate papillae were found. Considerable variation in size and shape was noted in all three types of papillae. Fungiform papillae varied from a type which resembled a filiform papilla to one which was similar to a circumvallate papilla with no moat surrounding it. They were tallest near the edges of the tongue. The fungiform papillae were found to vary in thickness from 0.2 mm. to 0.32 mm.; most of them being 0.2 mm. in diameter. This type of papilla in its typical form was found to be limited to the area of the tongue anterior to the circumvallate papillae. In the caudal region of the tongue, the circumvallate papillae were found in a "V" formation with the apex of the "V" directed caudad, as they are described by numerous histologists. They varied in diameter from 0.24 mm. to 0.62 mm. There seems to be a

great difference in size between these papillae and similar papillae of the human, for Bremer ('36) described the adult human papillae to be from 1 mm. to 3 mm. in diameter.

The taste bud of the pup was found to be an ellipsoidal shaped body with a diameter of 40 micra and a longitudinal axis of 60 micra. The taste bud in the right side of the top of the fungiform papilla illustrated in Figure 1 shows cellular relationships of the taste bud. The large peripheral lightly stained cells are the supporting cells of the bud, and the long inner darkly stained ones are the gustatory cells. The outer and inner taste pores are both distinguishable.

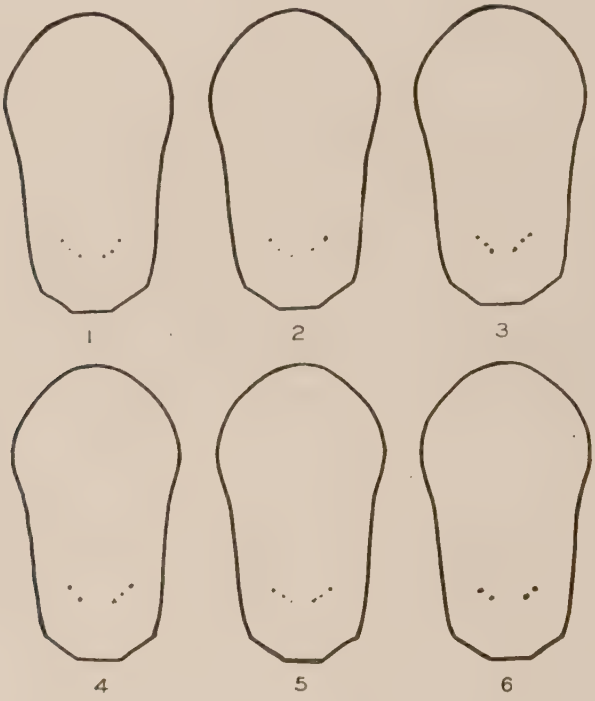

Fig. 2. Outline figures of six tongues to show uneven number and distribution of the circumvallate papillae. Figures 1 to 3 inclusive represent the tongues used in the histological study. Figures 4 to 6 inclusive represent the tongues used in the macroscopic study. (Actual size.)

In the pup, the taste buds of the tongue were found to be limited to its dorsal surface. In this area they were found only in the fungiform and circumvallate papillae. This was in agreement with the condition observed in the kitten by Elliott ('37), but it is contradictory to the location of taste buds in the child at birth as described by Bremer ('36) who states that in addition to buds being found in the two types of papillae just mentioned that they are also present in some of the filiform papillae. Schumacher ('27) describes fungiform papillae as appearing over the entire dorsum of the tongue and always possessing taste buds regardless of where they are located. The findings on the pup's tongue

are contradictory to this, for buds are found in these papillae only when they are located anterior to the circumvallate papillae.

The location of taste buds in the fungiform papillae have been described by various histologists as being present in the sides of these papillae; Elliott ('37) described them as having buds present in both the sides and tops. In this investigation buds were found to be present only in the tops of the fungiform papillae (Fig. 1). Olmsted ('21) gave four as the average number for buds present in this type of papilla of the dog. In his work on the kitten, Elliott ('37) found four to be the maximum number of buds present in any papilla. In the pup's tongue six was the maximum number of buds observed in a single papilla. This papilla was large and was located near the midline about midway between the tip of the tongue and the circumvallate papillae. In the

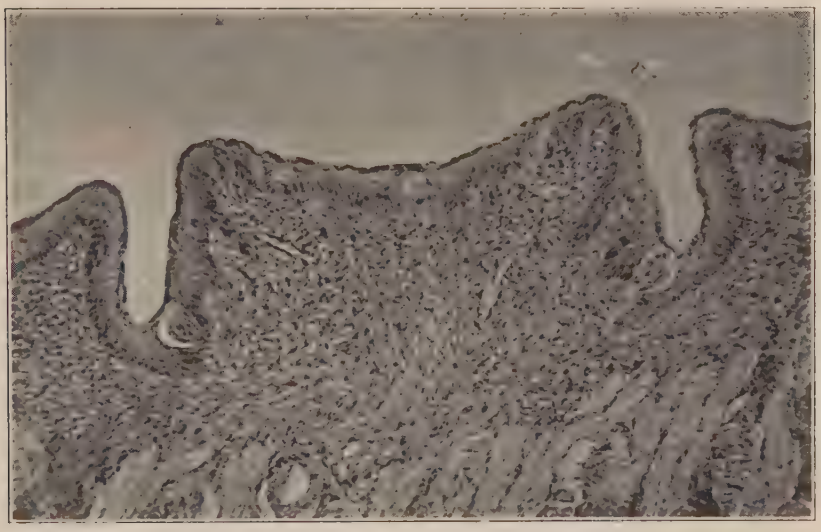

Fig. 3. Photomicrograph of a circumvallate papilla with two taste buds appearing in the floor of the trench. × 135.

present study, three was the average number of buds found in a papilla of this type.

Taste buds are described as being quite numerous in the infant by Schumacher ('27) and Arey et al ('35). The last mentioned investigators described the taste buds as occurring in patches. The results of the present study confirmed both of these points. In Table I is tabulated the number of taste buds exclusive of those found in the circumvallate papilla, found on all of the tongues used in the histological study. The total average number of the buds observed was found to be 1444 with a variation from the average of approximately 330 buds.

During the histological study of the tongue, it was noted that the circumvallate papillae were not constant either in number or in position. A study was made of the number present and their exact location plotted, as mentioned previously. The number present was found to

vary from four to six. These papillae were not in symmetrical arrangement, as shown by figure 2, for in tongue number 2, for example, four papillae were found to be present on the left side while only two were present on the right side. No median papilla was observed in any of the six tongues. This was held to prove further that no symmetrical arrangement existed, for when five papillae were present, as in tongue

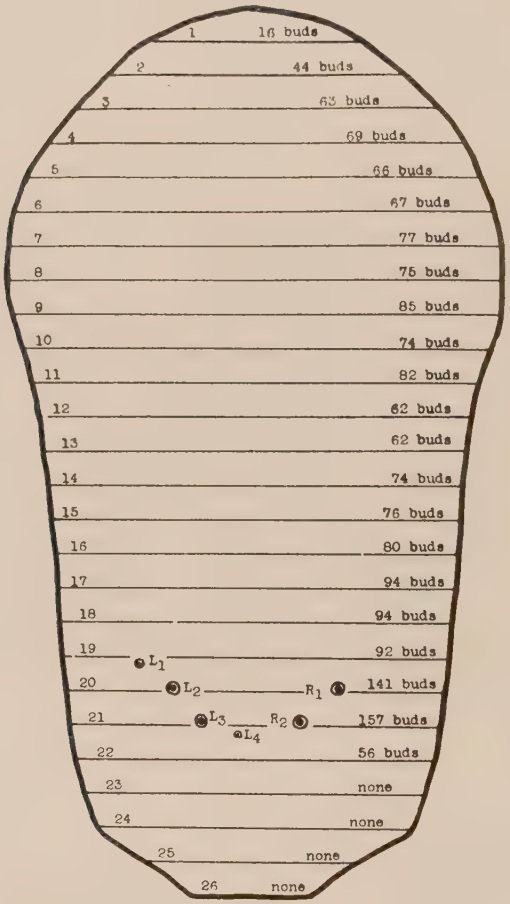

Fig. 4. Graphic representation of the average total regional distribution of taste buds over the entire dorsum of the three tongues studied for number of buds in fungiform papillae and for tongue number 2 studied for number of buds in circumvallate papillae. Each area represents seventy-three sections of a 20 micra tongue thickness. The positions of the circumvallate papillae in tongue number 2 are plotted. × 3.

number 4, three were found on the right half and two on the left half of the tongue.

The presence of this variation seems to be in agreement with the condition as described by Bailey ('21) for the human in which he stated that the circumvallate papillae in man varied from nine to fifteen in

number, but it is not in agreement with the arrangement of these papillae as described by Elliott ('37) in the kitten, for two circumvallate papillae were found in a single median trench, nor does it agree with the condition observed in the monkey by Vastarini-Cresi ('15), in which he found that a median circumvallate was present on the tongue of this mammal.

The region of the circumvallate papilla has been described by various histologists as the area of the tongue which possesses the keenest sense of taste. Addison ('26) estimated that 100 to 150 was the maximum number of taste buds present in a single circumvallate papilla of the human. Arey et al ('35) found that the number present varied with the age of the individual. They gave 788 buds for the papilla and 231 buds for the outer trench wall as the highest number observed in their work.

In this investigation, a count was made of the buds which were found in the circumvallate papillae of tongue number 2. Seventy was the greatest number of buds observed in any one papilla, these being found in papilla L_2, Figure 4; of these twenty-six were found in the top of the papilla and forty-four in the sides. The total number of buds observed in the circumvallate papillae of this tongue was two hundred sixty-two, of which one hundred twenty-one occurred in the tops, one hundred thirty-nine in the sides. Two buds were observed in the floor of the trench encircling circumvallate papilla L_3 of tongue 2 (Fig. 3). This last condition was described as rare but present in the human by Arey et al ('35). Probably the reason for the presence of a lower number in the pups than in the human is traceable to the difference in size of the papillae of these mammals, as previously mentioned. Taste buds are described as appearing in the outer wall of the trench in the human by Bailey ('21) and Arey et al ('35). None were observed in this position in the pup.

The author was interested in the shift of the acuity for lingual taste toward the region of the circumvallate papillae, as pointed out by Stahr ('01) in his work on the human and confirmed by Elliott ('37) for the case of the kitten; so, Figure 4 was prepared to obtain a more complete picture of the total number of taste buds of the different areas of the tongue. It can be noted that 1706 buds represents the average number present per tongue in this study. An area near the tip is quite well supplied with taste buds; this was mentioned for the dog by Olmsted ('21). There seems to be a slight shift in the keenness of the sense of taste toward the region of the circumvallate papillae where it would seem to be keenest by virtue of the great number of taste buds present.

CONCLUSIONS

1. In the pup all of the taste buds which are observed on the tongue are limited to the dorsal surface where they are found only in the fungiform and circumvallate papillae.

2. An average of 1706 buds per tongue was observed (Fig. 4). This average number is composed of 262 buds observed in the circumvallate papillae (of tongue number 2) and 1444 buds, the latter number being the total average number found in

the fungiform papillae of the three tongues used in this study. The total regional distribution of the buds in the fungiform papillae of all tongues studied is shown in Table I.

3. The taste buds found in connection with fungiform papillae were observed to be present only in the tops of such papillae. The greatest number of taste buds which was observed to occur in any fungiform papilla was six.

4. There is a very gradual increase in the number of taste buds from the tip of the tongue toward the circumvallate papillae. No taste buds were found caudad of the region of the circumvallate papillae (Fig. 4).

5. The circumvallate papillae were found to vary in number from four to six and this region contains the greatest number of taste buds (Fig. 4).

6. The taste buds observed in connection with the circumvallate papillae were found in the tops and sides and in the floor of the trench which surrounded the papillae (Fig. 3). Buds were found to be most numerous in the sides of such papillae.

7. In the adult human, taste buds are described as being present in the outer, trench wall (Arey et al '35). No buds were found in this position on the tongue of the pup.

REFERENCES

Addison. 1926. Piersol's Normal Histology. Lippincott, Philadelphia.

Arey, L. B., M. J. Tremaine and **F. L. Monzingo.** 1935. The numerical and topographical relations of taste buds to human circumvallate papillae throughout the life span. Anat. Rec., vol. 64, pp. 9–26.

Bailey. 1921. Textbook of Histology. Wm. Wood and Co., New York.

Bremer. 1936. Textbook of Histology. Blakiston, Philadelphia.

Elliott, Rush. 1937. Total distribution of taste buds on the tongue of the kitten at birth. J. Comp. Neur., vol. 66, pp. 361–373.

Guyer, M. F. 1936. Animal Micrology. The University of Chicago Press, Chicago, Illinois.

Hoffman, A. 1875. Über die Verbreitung der Geschmacksorgane beim Menschen. Virchow's Arch. für path. Anat., Bd. 62.

Lee, A. B. (Edited by J. B. Gatenby and T. S. Painter). 1937. The Microtomist's Vade-Mecum. J. & A. Churchill Ltd., London.

Maximow and **Bloom.** 1938. Textbook of Histology, W. B. Saunders Co., Philadelphia.

Olmsted, J. M. D. 1921. Effect of cutting the lingual nerve of the dog. J. Comp. Neur., vol. 33, pp. 149–154.

Ponzo, M. 1907. Intorno alla presenza do organi gustativi faccia inferiore della lingua del feto umano. Anat. Anz. Bd. 30.

Schumacher, S. 1927. Die Zunge. In v. Möllendorff'a "Handbuch d. mikr. Anat., d. Menschen." Bd. 5, Teil 1, S. 35–60.

Stahr, H. 1901. Über die Papillae fungiformes der Kinderzunge und ihre Bedeutung als Geschmacksorgan. Zeitschr. f. Morph. u. Anthrop., Bd. 4, S. 199–260.

Vastarini-Cresi, G. 1915. Chiasma gustativo (periferico) nella lingua dell 'normo e di alcuni mammiferi. Intern. Monatschr. Anat. Physiol., Bd. 31.

ON THE BIOLOGY OF DROSOPHILA IMMIGRANS STURTEVANT WITH SPECIAL REFERENCE TO THE GENETIC STRUCTURE OF POPULATIONS[1]

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TAXONOMY

The species which forms the subject of this account was first identified by Sturtevant (1918) as *Drosophila tripunctata* Loew. After re-examination of type material he described it as a new species, *Drosophila immigrans* (Sturtevant, 1921). Duda (1924) splits the Drosophila into a number of subgenera and places this species in the subgenus Spinulophila, subgen. n. He separates Drosophila s. str. from Spinulophila on the basis of a row of short, black bristles on the inner aspect of the first femur in the latter. Sturtevant (1939) in a recent careful study based on the comparison of many species of Drosophila in respect to a large series of external and internal characters has considered a number of Duda's subgenera to be invalid. He proposes dividing the genus into three subgenera. On this basis *D. immigrans* falls into the Drosophila s. str.

We include here the taxonomic description taken from Sturtevant's (1921) monograph on the North American species of Drosophila.

Male.—Arista with about six branches above and three below. Antennae yellow. Front over one-third width of head, wider above, yellow; ocellar dot dark brown. Second orbital one-fourth size of other two. Second oral bristle over one-half length of first. Carina broad, flat; face yellow. Proboscis yellow. Cheeks yellow; their greatest width about one-third greatest diameter of eyes. Eyes with rather thick pile.

Acrostichal hairs in eight rows; no prescutellars. Mesonotum and scutellum dull brownish-yellow. Pleurae and legs pale yellow. Apical and preapical bristles on first and second tibiae, preapicals on third. A row of very short, stout bristles on lower apical part of first femur. Basal joint of first tarsus about half as long as corresponding joint of middle leg, and thicker. Second tarsal joint of first leg also somewhat thickened and shortened.

Abdomen dull yellow, each of the four basal segments with an interrupted posterior black band. The band on the fourth segment is sometimes entire. Fifth segment black.

[1]Most of the work herein reported was done while the author held a General Education Board Fellowship under the Rockefeller Foundation. He wishes to thank Dr. A. H. Sturtevant for supplying certain stocks of flies and for collection of material at Woods Hole, and Dr. T. H. Morgan and staff for courtesies extended during time spent at the William G. Kerckhoff Laboratory of Biology, California Institute of Technology.

A single bristle at tip of first costal section (before distal break). Wings clouded at tips of first and second veins and on posterior crossvein. Costal index about 4.4; fourth-vein index about 1.2; 5x index about 1.0; 4c index about 0.5.

Length body 2.5 mm.; wing 2.7 mm.

Female.—Same as above, except basal tarsal joint of first leg about two-thirds as long as corresponding joint of second leg, not thicker. Second joint of tarsus of first leg not shortened or thickened.

GEOGRAPHICAL DISTRIBUTION AND ECOLOGY

Sturtevant (1921) gives many collection records from widely separated regions of the United States and from Costa Rica, Norway, Australia, and the Hawaiian Islands. The same author (Sturtevant, 1927) lists specimens from Formosa and India, and describes a new variety, *immigrans formosana.* Duda (1924) records it from Europe and Formosa, and Kikkawa and Peng (1939) from Japan. Sturtevant comments on its rarity in early collections, the first American specimens being taken in 1913. He thinks that it may be of Pacific origin. The presence of several closely similar forms in the Philippines and other parts of the Far East lends weight to this view. Today the species is very common throughout the United States. I have taken it in Massachusetts, New York, New Jersey, Pennsylvania, Tennessee, Ohio, Missouri, and California. It represents a highly successful introduced form in many sections and local communities of the United States.

Drosophila immigrans is more tolerant of low temperatures than a number of tropical species which form large summer populations in the northern part of the United States. *Drosophila hydei, melanogaster* and *simulans* are always completely killed off outdoors in this latitude, and overwinter only in buildings. Immigrans, on the contrary, is capable of surviving the milder winters outdoors, but is killed off by a severe season. This fact has been well established for northern Ohio through collections made over a period of years by Harrison Stalker and the author. In some years immigrans is rare or absent from fairly extensive spring collections, but even in these years it can be taken in abundance in the autumn. In other years, the summer of 1939 for example, following a mild winter immigrans appeared in numbers in collections of early summer from woods as well as in town.

It appears that *Drosophila immigrans* can breed in the woods, possibly on the same type of food as robusta, affinis, and

other non-fungus feeding woods species. However, it would seem to be more successful in town, breeding on over-ripe fruit, garbage, etc. Following a cold winter the few individuals which over-winter indoors give rise to a small spring population which gradually spreads, building up where food, temperature, and humidity are favorable and in many cases reaching woodland territory. If the following winter is mild flies over-winter in the woods, probably among leaves, under logs and rotting stumps, and in similar sheltered spots. These flies are then ready to build up a large spring population which will be represented in early summer collections from these localities. I have placed cultures of *Drosophila immigrans* outdoors in the autumn under air temperatures considerably below freezing, and have found that some of the flies survive after a two-day exposure.

Drosophila immigrans has a rapid life cycle, fourteen days from egg to egg under optimum conditions. These conditions are probably seldom reached under natural environments, particularly on account of the fall in night temperature even in summer to a point below that at which larvae grow most rapidly. However, this species has the shortest life cycle of the larger Drosophila. This fact, coupled with a high fecundity under favorable conditions, makes possible the building up of large populations within a short time in a given locality. Where seasonal fluctuations in temperature and moisture are limiting factors, a few days difference in length of life cycle has an important bearing on the flaring out of populations from small foci, the time at which an approximate breeding equilibrium may be reached, and the degree of homogeniety of local colonies which have bred up to a point where all available food is being used.

Drosophila immigrans, breeding in the northern United States, is a species which in mild years is likely to form spring and early summer populations large in area but low in density, breeding in the woods as well as in towns, on food similar to that used by typical native woods species. The dense localized populations developing later in the summer on accumulations of refuse, decaying fruit, etc., are likely to have sprung from migrants working in from many surrounding sources. In contrast, after a hard winter there will be no widespread spring and early summer populations and the dense aggregates formed in late summer and early autumn will be more spotty in distribution and homogeneous in structure, due to their development

from small localized foci of flies over-wintering indoors or in particularly favorable locations for winter survival. The migration out into woodland territory in such a season will progress into the autmun providing the proper humidity conditions are present.

A study of Drosophila populations breeding on a large citrus dump near Azusa, Southern California, and on a refuse heap from a canning factory and fruit and grocery wholesaler near Wooster, Ohio, has given some data on the breeding habits of the species present. In both places *Drosophila hydei* is the dominant form. Immigrans, melanogaster, simulans, and buskii are found in smaller numbers. Others also occur but in still less abundance. In both situations almost pure stands of hydei in all stages of development may be found in many parts of the breeding ground. However, small areas may be found where immigrans or melanogaster predominate in collections of larvae, pupae, and adults. An explanation of this localized concentration of minorities in a habitat where one species is vastly in the majority depends on a knowledge of such factors as breeding habits, micro-environments, and the actual sequence of events necessary to ensure the inception and continued development of a given generation of a species. Actually, both in California and Ohio the flies seek shelter from the direct rays of the hot, mid-day sun. Then in late afternoon they come out and feed voraciously in spots where the humidity is high and the food supply abundant and of the right quality. This occurs at relatively high temperatures. As the temperature continues to drop in the late afternoon courting and copulation occur. At a still lower temperature oviposition takes place in humid areas which are likely to be protected from rapid drying. A favorite place for egg-laying is a crevice in relatively fresh food. There is often some desultory inter-specific courting, but the tendency is for groups of one species to congregate in a limited area. This is followed by intra-specific courting and copulation. It seems likely, although the observation has not been made, that the females remain close to the point of copulation and deposit their eggs in the immediate vicinity later in the evening. The output from a few dozen females would be sufficient to account for these small local populations of a minority species observed here and there in the general habitat. Whether there is some local favorable stimulus which draws a minority species together at a given point I have been unable to determine. It may only

be that the mutual attraction of individuals of a given species tends to form concentrated local groups at copulation and egg-laying time. One gets the impression that both immigrans and melanogaster populations are breeding on fresher food than hydei (Spencer, 1932)

There is no doubt but that adults, pupae, and larvae of immigrans as well as other species are capable of withstanding much higher temperatures outdoors than in bottle culture without sterilization or injury. This seems in large part due to the removal of deleterious gases as carbon dioxide under the better ventilation of the natural environment. Furthermore, rapid evaporation from surfaces exposed to air of low or medium humidity undoubtedly lowers the temperature in the micro-environment of the air film of a couple of millimeters thickness to which the fly is actually exposed when resting on the surface in question.

PHYSIOLOGY

A number of facts of interest concerning the life cycle and physiology of this fly have been observed, some of which have an important bearing upon its adaptability as a form for genetic study. As stated above, the life cycle under optimum conditions is fourteen days. This may be divided into egg, larval, pupal, and adult periods. The eggs are much smaller than in most Drosophila species, have four tapering filaments, and are buried deeply in the food medium when this consists of corn-meal or banana agar. They require approximately thirty hours to hatch at 24 C. Both larvae and adults are very sensitive to acidity and excess carbon dioxide formation in vial or bottle cultures. For this reason high temperatures should be avoided where fermentation is likely to occur, as in cultures where yeast is being grown. Immigrans larvae grow quite well on Fleischmann's yeast suspension, using "kleenex" tissue as a base. Flies from larvae grown on this medium are large and vigorous. Where yeast suspension is used for the larvae, adults may be fed on corn-meal molasses agar with a minimum of yeast. The use of "moldex" has made the culture of immigrans much easier, as this ingredient in the medium cuts down bacterial, mold, and yeast growth to a point where there is little danger of adult flies being injured by carbon dioxide formation at temperatures below 25 C.

Immigrans is similar to hydei and melanica and unlike virilis and funebris in requiring re-culturing for each new generation. It is not safe to add fresh food to old culture bottles of immigrans as the whole culture is likely to deteriorate from bacterial growths. With funebris or virilis the addition of fresh food to old cultures keeps them running indefinitely. The difference in species in regard to the length of time they may be kept without re-culturing seems to depend on the ability of their larvae to utilize old, worked-over media, and the tendency for certain species to be associated with bacterial growths which prove deleterious.

The species is intermediate in activity between such active forms as melanogaster, simulans, hydei, and repleta and sluggish types as funebris and robusta. It etherizes slightly faster than melanogaster and slower than robusta, which places it about the center of the range of etherization-time of the species of Drosophila investigated. It has the habit of defecating as it goes under ether. This is likely to prove inconvenient for the investigator where large numbers of immigrans are being etherized. To keep the flies clean it is advisable to use a large etherizer or to handle fewer flies at a time.

Of all the species studied the males of immigrans become sexually mature the earliest after eclosion. Within from four to six hours after emergence males have been observed copulating. Although females do not begin ovipositing for three to four days they may be impregnated soon after eclosion. The flies remain in copulation for as much as an hour in some cases. The extreme sexual precocity of the male is a serious handicap to the use of this species for extensive genetic work requiring controlled matings of diverse stocks.

CYTOLOGY

Metz (1916) first described the metaphase chromosomes as consisting of three rods and a V. Stella (1936) has corroborated this finding. This author has made a study of oogenesis, following the methods used by Guyenot and Naville, and finds that unlike melanogaster no premeiotic and meiotic stages are to be found either in young or old female pupae. Meiosis in immigrans begins after the emergence of the female and can be studied by fixing ovaries from young females. Early embryonic mitoses occur five to six hours after egg-laying.

Emmens (1937) has made a study of salivary gland nuclei in this and three other species. He finds five chromosome arms as would be expected from the three rods and a V-shaped chromosome in metaphase plates. He finds the chromocenter to be larger and more diffuse than in melanogaster and funebris. He describes an element unique in the salivary nucleus of immigrans under the name of "striated body." This consists of a wide, short element, with four or six bands. He interprets this as probably consisting of the proximal ends of several or all the chromosomes fused laterally. The suggestion is also made that this body might consist of fused trabants from several chromosomes.

TABLE I

A List of Mutants of *Drosophila immigrans* Described by Various Workers. Autosomal recessive marked a. r.; sex-linked recessive marked s. r.

	Name	Phenotypic Effect	Described by	Date
1	Abnormal a. r.	Plexus veins	Bischler and Piquet	1931
2	Axillary a. r.	Venation	Metz and Metz	1915
3	Brown s. r.	Eye color	Bischler and Piquet	1931
4	Carmine opaque a. r.	Eye color	Bischler and Piquet	1931
5	Extra bristles	Dorso-centrals	Bischler and Piquet	1931
6	Ski	Upturned wings	Bischler and Piquet	1931
7	Spread a. r.	Wing position	Bischler and Piquet	1931
8	Truncated a. r.	Bristles	Bischler and Piquet	1931
9	Yellow s. r.	Body color	Stella	1936
10	..... s. r.	Small-wing	Sturtevant	1921
11	..... a. r.	Small bristles	Sturtevant	1921
12	..... a. r.	Modified veins	Sturtevant	1921
13	..... a. r.	Modified veins	Sturtevant	1921
14	..... a. r.	Modified veins	Sturtevant	1921

GENETICS, SUMMARY OF DESCRIBED MUTANTS

In Table I is given a summary of the data on mutants published up to the present time in this species. Of the fourteen mutants described, nine were autosomal recessives, three sex-linked recessives and two not analyzed. Of these only yellow body, sex-linked recessive reported by Stella (1936), is clearly a parallel of mutants found in other species, although the others might well be parallels as they are similar to mutants known for other flies. The abnormal venation of Bischler and Piquet (1931) and possibly two of the venation mutants reported by Sturtevant (1921) may be alleles at the "net" locus (see below).

GENETICS, NEW MUTANTS

In Table II is given a summary of new mutants, hitherto unpublished. These were found by the author, except for three discovered by Sturtevant and turned over to the author. Sturtevant has also found several other cases of "net," which are probably alleles of those reported here. There follows a brief description of each of the mutants listed in Table II. A number of these have been described briefly in Drosophila Information Service, No. 11, and there assigned a symbol. It is not deemed advisable to publish symbols here as the stocks have been discarded. Consequently anyone in future making a genetic study of this species will not have the confusing situation of avoiding the use of symbols assigned to mutants no longer extant in laboratory stocks. The descriptions are necessarily brief, but it is hoped that they have been made sufficiently specific and clear that they may be used for comparative purposes. Of the thirty-seven mutants described all but four were kept in stock for several generations, either in pure form or through the mating of heterozygotes when sterility was involved. The four not carried in stock were distinct enough in phenotypic effect and appeared in sufficient numbers in F_2 cultures from wild flies to make certain that they were true mutant types and not aberrant forms due to some developmental "accident." Many of the stocks were carried for two years. They have been discarded through the press of other work and the conclusion that the detailed study of linkage in the species was not advisable, owing to the technical difficulty referred to above.

Cherry. Sex-linked recessive. A translucent eye color found in one male of a stock derived from wild flies collected at Gatlinburg, Tennessee. It probably arose as a laboratory mutant not present in the original wild material. Classification easy and viability good.

Singed. Sex-linked recessive. Mutant causing a singing of all bristles and hairs, including marginal bristles of wing. Several singed males were found in a mass culture descended from a pair of wild flies collected in Wooster, Ohio. Females were sterile, males with fair viability and fertility. This seems a clear parallel of singed in melanogaster and other species, and represents a medium to extreme allele.

Brown. Autosomal recessive. A dark eye color, easily classified at eclosion and darkening with age to almost black. The original name given in DIS 3 is retained, although this is more like weak sepia or clot of melanogaster. Found as one female in mass culture from stock of wild flies collected in Wooster.

Burnt. Autosomal recessive. A peculiar mosaic eye color from wild stock, Azusa 17. This and almost all of the remaining mutants

described appeared as several flies segregating out of F_2 mass cultures reared from females either impregnated before capture or mated to a single wild male taken at the same time. The burnt character consisted

TABLE II

A List of *Drosophila immigrans* Mutants Described in This Paper

	Name	Phenotypic Effect	From Wild Stock
Sex-linked Recessives			
15	Cherry	Eye color	Gatlinburg
16	Singed	Bristles	Wooster
Autosomal Recessives			
17	Brown	Eye color	Wooster
18	Burnt	Eye color	Azusa, 17
19	Curly	Wing shape	Azusa, 24
20	Dark	Eye color	Azusa, 8
21	Extra	Venation	Wooster
22	Extra dorso-centrals.	Bristles	Woods Hole
23	Extra scutellars	Bristles	Azusa
24	Forked scutellars	Bristles	Azusa, 30
25	Grooveless	Scutellar groove	Azusa, 14
26	Irregular	Hairs, wings	Azusa, 1
27	Irregular	Hairs, wings	Azusa, 8
28	Javelin	Bristles	Arroyo Seco
29	Minute	Bristles	Rincon, 17
30	Minute mosaic	Bristles	Azusa, 5
31	Net	Venation	Azusa, 13
32	Net	Venation	Azusa, 24
33	Net	Venation	Azusa, 29
34	Net	Venation	Rincon, 5
35	Net	Venation	Rincon, 14
36	Net	Venation	Gatlinburg
37	Net	Venation	Gatlinburg
38	Net	Venation	Woods Hole
39	Ocelliless	Bristles, ocelli	Azusa, 3
40	Peach	Eye color	Azusa, 5
41	Peach-like	Eye color	Azusa
42	Rough	Eye texture, veins	Azusa, 5
43	Rough-like	Eye texture, veins	Azusa, 17
44	Rough-like	Eye texture, veins	Rincon, 8
45	Slight dark	Eye color	Rincon, 2
46	Slight dark	Eye color	Wooster, 3
47	Small eye	Eye shape, texture	Rincon, 18
48	Stubby	Bristles	Woods Hole, 43
49	Stubby-like	Bristles	Gatlinburg
50	Two bristle	Bristles	Azusa, 10
51	Two bristle	Bristles	Woods Hole, 69

Note.—Javelin, net Azusa 13, and peach-like found by A. H. Sturtevant and turned over to the author for study. All other mutants listed here were found in 1937 except brown (1934), cherry (1938), extra (1933), two Gatlinburg nets and stubby-like (1938).

of a dark area of variable size, located near the center of the eye if small; sometimes covering most of the eye. Young, unetherized flies failed to show this. When etherized the burnt area rapidly appeared,

and did not again fade out. Old flies without etherization developed this dark area. Frequently the area had a shiny, seared appearance. The mutant also colored the malpighian tubules a bright salmon. Burnt was somewhat infertile and showed great variability in expression, but with few normal overlaps.

Curly. Autosomal recessive. Wings curled upward as in the dominant Curly of melanogaster. A mutant of very poor viability, and partially sterile. Owing to sterility of females a pure stock was never established. From Azusa 24.

Dark. Autosomal recessive. A dull, dark eye color, somewhat variable and difficult to classify in some cultures. From Azusa 8.

Extra. Autosomal recessive. A slight venation mutant, consisting of small cross-vein or several of these near the distal terminus of the second longitudinal. Normal overlaps. From wild stock collected in Wooster.

Extra dorso-centrals. Autosomal recessive. Two or more extra dorsocentral bristles. Variable in expression. This character is frequently met with in wild collections of immigrans but segregated rather definitely in certain wild strains collected from Woods Hole, Massachusetts, while not appearing in others and is consequently listed as a mutant.

Extra scutellars. Autosomal recessive. Extra anterior scutellar bristles of about equal size to the normal ones and lying close to them. Very inconstant in expression. From wild stock of Azusa flies.

Forked scutellars. Autosomal recessive. Anterior scutellars gnarled or forked. Often poorly expressed with many normal overlaps. From Azusa 30.

Grooveless. Autosomal recessive. Similar to the fourth chromosome mutant of this name in melanogaster. When first found the character was well expressed, with the entire lack of a groove between scutellum and thorax. However, there were no dark excrescences on thorax as in melanogaster and hydei. After several generations the expression became less marked with normal overlaps. Since grooveless was recovered from outcrosses modifiers may have accumulated. From Azusa 14.

Irregular. Autosomal recessive. Bristles along margin of wing standing out at a wide angle; hairs on abdominal tergites disarranged; hairs on thorax disarranged; wings somewhat shorter than normal and held out at an angle. Similar to mutant by same name described by Chino (1929) in Drosophila virilis, and found by the author in hydei, melanogaster, robusta, and an undescribed species in the repleta group (all unpublished). This seems to represent an extreme type by comparison with the others. From Azusa 1.

Irregular. Autosomal recessive. Bristles along margin of wing standing out at wide angle; hairs of abdominal tergites slightly disarranged, but thoracic hairs normal and wings only slightly shortened. A slight allele as shown by mating tests with extreme irregular. From Azusa 8.

Javelin. Autosomal recessive. Mutant found by A. H. Sturtevant in wild stock from the Arroyo Seco, a canyon in the San Gabriel mountains near Pasadena. Bristles long, not tapering at the end as in wild-type; often hooked at end. Similar to mutant of same name in melanogaster.

Minute. Autosomal recessive. Very small bristles; low viability and fertility; pure stock not established. From Rincon 17.

Minute mosaic. Autosomal recessive. Small bristles in a mosaic pattern; anterior scutellars most often affected; less frequently dorsocentrals and head bristles; pattern seemed to show no symmetry. From Azusa 5.

Net. Autosomal recessive. Found by A. H. Sturtevant in his stock Azusa 13, from a single female collected near Azusa. This was a very extreme net venation with a heavy plexus over most of the surface of the wing, and particularly concentrated around the posterior cross-vein and along margin of wing between first and second longitudinals. Although there was much variability in a culture all flies showed the character in extreme form. This mutant in some cases showed weak net manifestation in heterozygous form when crossed to stock showing no visible net, indicating that extreme net, Azusa 13, is partially dominant to some phenotypically wild-type alleles.

Net. Autosomal recessive. This and the following cases of net seem to represent various alleles at the frequently mutating net locus in this species. While tests for allelism were not made in all combinations, in cases where they were made the results were consistent with the view that there was a large series of multiple alleles at the net locus, distributed through wild populations. This is a situation somewhat similar to the case of the multiple allelic series of "bobbed" in Drosophila hydei (Spencer, 1937). This was a net of medium grade of expression, with plexus of veins developed around posterior cross-vein. From Azusa 24.

Net. Autosomal recessive. Weak expression, but no normal overlaps. Small sections of vein around posterior cross-vein and between first and second longitudinals. From Azusa 29.

Net. Autosomal recessive. Medium expression. From Rincon 5.

Net. Autosomal recessive. Medium to weak expression. From Rincon 14.

Net. Autosomal recessive. Medium to weak. From Gatlinburg.

Net. Autosomal recessive. Weak expression. From Gatlinburg.

Net. Autosomal recessive. Very weak expression. Recovered in ten cases from tests of 156 wild flies from Woods Hole. In appearance these all seemed very similar and might readily have come from a single source (see discussion below).

Ocelliless. Autosomal recessive. Similar to mutant of the same name described by the author in Drosophila funebris (Spencer, 1928). Hairs sparse on thorax and abdomen, wing marginal bristles ragged; ocellar bristles sometimes missing; ocelli may be missing or run together; eye pile sparse; wings thin textured; sometimes hairs or bristles doubled and coming from same basal ring; partially sterile and inviable. From Azusa 3.

Peach. Autosomal recessive. Translucent eye color when newly emerged; darkening with age. From Azusa 5.

Peach-like. Autosomal recessive. Translucent eye color, somewhat easier to classify than peach. Found by A. H. Sturtevant in Azusa wild stock.

Rough. Autosomal recessive. Extreme rough eye; venation ragged and wings thin textured. Semi-sterile. From Azusa 5.

Rough-like. Autosomal recessive. Similar to rough of Azusa 5, but less extreme. Allelism not tested due to difficulty of breeding rough. From Azusa 17.

Rough-like. Autosomal recessive. Almost identical to rough of Azusa 5, but allelism not tested. From Rincon 8.

Slight dark. Autosomal recessive. Dark eye; not as extreme as brown and frequently difficult to classify. From Rincon 2.

Slight dark. Autosomal recessive. Phenotypically similar to slight dark from Rincon 2; allelism not tested. From Wooster 3.

Small eye. Autosomal recessive. Small, rough eye with anterior scutellars missing on most flies. Inviable and sterile. From Rincon 18.

Stubby. Autosomal recessive. All head and thoracic bristles short and thick. Viability and fertility good, and classification easy. From Woods Hole 43.

Stubby-like. Autosomal recessive. Similar to stubby of Woods Hole 43. Allelism not tested. From Gatlinburg.

Two bristle. Autosomal recessive. Anterior dorso-central bristles missing. Good expression, but with a few normal overlaps. The species often gives expression to extra dorso-centrals. This mutant has a phenotypic effect opposite to the general trend of the species. From Azusa 10.

Two bristle. Autosomal recessive. A mutant similar to the one just described but with many more normal overlaps. From Woods Hole 69.

In addition to the above mutants the author has recorded several cases of weakly expressed and inconstant hereditary types. In any study of visible mutants it becomes obvious that there are many grades ranging from those which under any environmental conditions which will allow for the development of the flies show a constant and uniform character expression to those inherited tendencies which give no visible effects under some conditions and only feeble and inconstant characters under other conditions. In spite of this range of character expression it is possible to list in a given investigation those mutants which show about the degrees of expression at a phenotypic level generally worked with by students of Drosophila genetics. The argument is sometimes advanced that lethal genes can be handled more objectively. However, to those familiar with the gradations from what appear to be 100% recessive lethals, through semi-lethals which under slightly adverse culture conditions show 100% lethal expression, to mutants of low viability, this argument should have little weight. The accuracy of the comparison and contrast of data collected from different sources, as in the study of diverse populations reported here, will depend less on where the line

is drawn as regards classifying of attenuated phenotypic effects as mutant types, than on drawing that line at about the same point for all sets of data under consideration. Furthermore, a thorough familiarity with the peculiarities exhibited by a species under various conditions of culture, against a background of experience gained through the study of other species, is probably more important than the setting up of arbitrary rules of classification to be followed blindly. While it may appear to be a dangerous practice it is none the less important that an investigator be prepared to evaluate results from a particular experiment in terms of all that he knows of possible factors involved in giving the results.

At best, however, it is impossible to carry on investigations which deal either with the origin of new mutants or the distribution of mutants already present in a population without some subjective error. These errors are less when the amount of data treated is large, and when the data are collected by one rather than by several workers.

LINKAGE STUDIES

The X-Chromosome. The sex-linked recessives, brown eyes (Bischler and Piquet, 1931), cherry eyes (Spencer), small wing (Sturtevant, 1921), singed bristles (Spencer), and yellow body (Stella, 1936) have been recorded. However, these mutants were found at various times in widely separated laboratories and no linkage studies on the X-chromosome have been carried out. Singed and yellow are clearly parallels of mutants found in the X of many other species, and the others might well be parallels, although their identity is not so readily determined.

Autosomal Linkage. Bischler and Piquet (1931) report linkage between spread wings and carmine opaque eyes.

Sturtevant (unpublished) found that net and brown were linked.

I have added to this linkage group the gene rough, Azusa 5, and find that peach, Azusa 5, and javelin are in the same linkage group and not linked to brown-net-rough.

Thus three of the four expected linkage groups have been established from the investigation of a few of the mutants reported here. The author made preliminary attempts to secure further linkage data, but these were unsuccessful owing to the difficulty of securing virgin females for tests, as noted above.

No cross-over data are available, and the genetic chromosomes of this species remain wholly unmapped, Linkage studies on *Drosophila immigrans* would be possible, but could only be carried through successfully by one with much time available for the work.

GENETIC STRUCTURE OF POPULATIONS

The new mutants found by the author have been extracted from five geographically distinct populations. It is realized that the samples studied were inadequate in size and that the method of analysis was less accurate than those used by Dubinin and collaborators (1934), Gordon (1936), and the Timofeeffs-Ressovsky (1927) for the analysis of visibles in *Drosophila melanogaster* populations, or of Spencer (in press) for similar work on *Drosophila hydei*.

Wild flies were trapped at Camp Rincon, San Gabriel Canyon, Southern California; a large citrus dump near Azusa, Southern California; Gatlinburg, Tennessee; Woods Hole, Massachusetts (two stations); and a refuse dump from a canning factory, Wooster, Ohio.

The method of analysis consisted of rearing an F_1 generation either from a female impregnated before capture or from a pair of flies taken from traps and mated in the laboratory. One or two F_2 mass cultures were reared from about a dozen of the F_1 flies. Neither lethals nor chromosomal variations were studied. If random mating occurred among the F_1 flies, then approximately one-sixteenth of the F_2 flies should be homozygous for a given recessive autosomal mutant carried in heterozygous form by one of the original parents. The inaccuracy of the method consists in part in the practical certainty that the F_2 flies are not produced at random from all the F_1 parents used. This has been proved when the method of rearing the F_2 from several separate pair matings is directly compared to the F_2 mass culture method. However, as the same technique was used throughout these analyses are directly comparable.

Table III summarizes the results from the several populations as to the number of flies tested from each region and the number of separable visible mutants or alleles of these recovered. In this table the chi square test has been applied to determine whether the distribution of visible mutants recovered is random for the five populations studied. By this test it is found that the distribution is far from random, the deviations

being highly significant. A much larger group of mutants was discovered for the size of the sample taken from Azusa than for the sample from Woods Hole. The Wooster and Rincon populations show small deviations from expectation, while the Gatlinburg population contained very nearly the same proportion of mutants as that found for all the samples together.

These facts may be explained by reference to the pattern of the populations in question. At Woods Hole the species is probably killed off outdoors in the winter. The Woods Hole collections taken at two trapping stations about one-half mile

TABLE III

SUMMARY OF WILD FLIES TESTED AND AUTOSOMAL RECESSIVE MUTANTS RECOVERED FROM FIVE GEOGRAPHICALLY DISTINCT POPULATIONS OF *Drosophila immigrans* AND CALCULATION OF CHI SQUARE AS A TEST OF THEIR RANDOM DISTRIBUTION

LOCALITY OF POPULATION	TOTAL NUMBER WILD FLIES TESTED, n	NUMBER OF DISTINCT MUTANTS RECOVERED, X	NUMBER OF MUTANTS EXPECTED m	$\frac{362}{330} \cdot \frac{(X-m)^2}{m}$
Azusa, California	60	16	5.304	23.661
Camp Rincon, California	56	6	4.950	0.245
Gatlinburg, Tennessee	44	4	3.890	0.003
Woods Hole, Massachusetts	156	4	13.790	7.624
Wooster, Ohio	46	2	4.066	1.152
Totals	362	32	32.000	$32.69 = \chi^2$ d. f. = 4

Probability of chi square being 13.277 or greater is 0.01; as chi square is actually 32.69 the deviation from a chance or random distribution of distinct mutants in the five populations is such as would happen much less often than once in 100 trials and is clearly significant.

apart in late July came in all probability from small local foci which had overwintered indoors. The fact that a net mutant of mild expression was found ten times in the sample of 156 flies tested is indicative of this. Two other mutants were also found several times. In all only four distinct types were recovered. In contrast sixteen distinct mutants were extracted from 60 flies tested from Azusa. Here the species survives the year round outdoors, although the population must be markedly decreased during the hot, dry summer. The effective breeding population at the Azusa citrus dump is quite conceivably much larger than that of Woods Hole, where the breeding aggregate

contracts yearly into an indoors "bottle-neck." These data are in line with the mathematical analysis of Wright (1931) on the breeding structure of Mendelian populations. The figures are small and the analysis somewhat faulty. However, the evidence presented here indicates the importance of the size of populations at different times of the year in determining their genetic structure.

SUMMARY

1. The taxonomic position of *Drosophila immigrans* is reviewed.

2. Known facts of its distribution in Europe, Asia, and North America are given.

3. Collection data show that in mild seasons the species may over-winter outdoors in northern Ohio; in severe winters it survives only in buildings. This affects the structure of the summer and autumn populations in a given season.

4. Immigrans forms small, local aggregates in breeding grounds where *Drosophila hydei* is the dominant form.

5. The species tolerates higher temperatures outdoors than in bottle cultures, probably due to better ventilation.

6. Larvae and adults are very sensitive to acidity and to accumulation of carbon dioxide. Larvae grow well on a "kleenex" yeast suspension medium.

7. Males show extreme sexual precocity, making controlled matings of diverse stocks difficult.

8. The cytology is reviewed briefly. There are three pairs of rods and one pair of V-shaped chromosomes. The salivary chromosomes show five long elements.

9. A summarized table of 14 mutants from descriptions in the literature is given.

10. A table and brief descriptions of 37 new mutant types are presented.

11. Of these a multiple allelic series at the "net" locus is most interesting. Evidence presented indicates that net is widely spread throughout immigrans populations.

12. Sex-linked yellow and singed are clear parallels of mutants of the same names in other species. Other parallels are not so evident.

13. In Table III appears a summary of the genetic analysis for recessive visible mutants present in 362 wild flies from populations at Camp Rincon and Azusa, Southern California; Gatlinburg, Tennessee; Woods Hole, Massachusetts; and Wooster, Ohio.

14. The chi-squared test shows that the mutants recovered were not distributed at random to these five populations.

15. The excess of mutants at Azusa and their scarcity at Woods Hole are interpreted in terms of the breeding structures of the populations involved.

LITERATURE CITED

Bischler, V., and **J. Piquet.** 1931. Quelques mutations spontanees de Drosophila immigrans. C. R. Soc. Biol. Paris, 108: 1027–1029.

Chino, M. 1929. Genetic studies on the Japanese stock of Drosophila virilis. Jap. J. Genetics, 4: 117–131.

Dubinin, N. P., and collaborators. 1934. Experimental study of the ecogenotypes of Drosophila melanogaster. Biol. Zh., 3: 166–206.

Duda, O. 1924. Beitrag zur Systematik der Drosophiliden unter besonderer Berucksichtigung der palaarktischen u. orientalischen Arten (Dipteren). Arch. Naturgesch., 90: 172–234.

Emmens, C. W. 1937. The morphology of the nucleus in the salivary glands of four species of Drosophila (*D. melanogaster*, *D. immigrans*, *D. funebris*, and *D. subobscura*). Z. Zellforsch., 26: 1–20.

Gordon, C. 1936. The frequency of heterozygosis in free-living populations of *Drosophila melanogaster* and *Drosophila subobscura*. J. Genetics, 33: 25–60.

Kikkawa, H., and **F. T. Peng.** 1938. Drosophila species of Japan and adjacent localities. Jap. J. Zool., 7: 507–552.

Metz, C. W. 1916. Chromosome studies on the Diptera. III. Additional types of chromosome groups in the Drosophilidae. Amer. Nat., 50: 587–599.

Metz, C. W., and **B. S. Metz.** 1915. Mutations in two species of Drosophila. Amer. Nat., 49: 187–189.

Spencer, W. P. 1928. New mutations in Drosophila funebris Fabricius. J. Exp. Zool., 51: 177–197.

1932. The vermilion mutant of *Drosophila hydei* breeding in nature. Amer. Nat., 66: 474–479.

1937. Multiple alleles at the bobbed locus in populations of *Drosophila hydei*. Rec. Genet. Soc. Amer., 6.

Stella, E. 1936. Etudes genetiques et cytologiques sur Drosophila immigrans Sturt. Rev. suisse Zool., 43: 397–414.

Sturtevant, A. H. 1918. A synopsis of the Nearctic species of the genus Drosophila (sensu lato). Bull. Amer. Mus. Nat. Hist., 38: 441–446.

1921. The North American species of Drosophila. Publ. Carneg. Instn., No. 301: 150 pp.

1927. Philippine and other oriental Drosophilidae. Philipp. J. Sci., 32: 361–374.

1939. On the subdivision of the genus Drosophila. Proc. Nat. Acad. Sci., 25: 137–141.

Timofeeff-Ressovsky, H. A., and **N. W. Timofeeff-Ressovsky.** 1927. Genetische Analyse einer freilebenden *Drosophila melanogaster*-Population. Arch. EntwMech. Org., 109: 70–109.

Wright, S. 1931. Evolution in Mendelian populations. Genetics, 16: 97–159.

TWO NEW BUPRESTIDAE

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Dystaxiella n. gen.

I propose this genus for a species which appears to be intermediate between *Glyptoscelimorpha* and *Dystaxia*. From the former genus, which it more closely resembles, it differs by the cleft tarsal claws and the large white scaly vestiture. From the latter genus it differs by the convex pronotum and lack of dense, coarse dorsal punctures.

Genotype *Dystaxiella juniperae* n. sp.

Dystaxiella juniperae n. sp.

Male.—Form of *Glyptoscelimorpha marmorata* Horn, but larger, brunneous throughout with exception of eyes which are dark mottled with irregular light areas, clothed with recumbent elongate scales which are more abundant on the ventral surface and partly conceal the punctures.

Head convex, a median line on vertex; clypeus broadly emarginate in front; surface densely, finely punctured, punctures separated by more than their own diameters; antennae reaching nearly to middle of elytra when laid along sides, scape stout, second joint about twice as long as wide, third joint longest, following joints decreasing in length, joints five to eleven inclusive serrate.

Pronotum nearly twice as wide as long, much wider at base than at apex, widest at base; sides constricted at apex, broadly rounded to base; disk convex, lateral marginal carina obsolete in front; surface densely punctured, punctures larger than those of head. Scutellum triangular, glabrous.

Elytra at base much wider than pronotum, widest back of humeral angles, sides rounded in front, constricted about middle, broadly rounded posteriorly to rounded apices; disk convex; surface densely punctured, punctures same size as those of head.

Abdomen beneath densely finely punctured, last abdominal segment with a deep V-shaped emargination. Tarsal claws with a tooth on the inside near the apex of each claw.

Length 9.3 mm.; width 4 mm.

Female.—Differs from the male by the rounded last abdominal segment and the shorter antennae which reach just beyond the hind angles of the pronotum.

Described from specimens taken on juniper (*Juniperus* sp.) at Mountain Springs, California, July 26, 1940, by D. J. and J. N. Knull. Type material in collection of writer.

Cinyra cuprescens n. sp.

Male.—Robust, convex, dark cupreous throughout.

Head convex, no depressions; surface with very large punctures; clypeus broadly emarginate; surface clothed with white pubescence; antennae reaching past middle of pronotum when laid along side; serrate from the fourth joint.

Pronotum wider than long, wider at base than at apex, widest back of middle; sides widened posteriorly, nearly parallel at base; anterior margin slightly sinuate, median lobe very broad; basal margin sinuate, median lobe broad; disk convex, lateral marginal carina obsolete in front; surface coarsely punctured, punctures more numerous on sides, separated by less than their own diameters in center, pubescence inconspicuous. Scutellum oval, glabrous.

Elytra wider than pronotum, widest back of middle; sides rounded in front, constricted near middle, broadly rounded posteriorly, apices emarginately truncate, outer angles acute; disk convex, basal depressions slight; surface striate, interspaces coarsely irregularly punctured, punctures not as large as those of pronotum, pubescence inconspicuous.

Abdomen beneath coarsely confluently punctured, densely pubescent, last abdominal truncate.

Length 10.7 mm.; width 3.2 mm.

Female.—Differs from male by being larger in size, with more convex abdomen and antennae not reaching middle of pronotum when laid along side.

Material collected in the Tucson Mountains, Arizona, August 18–19, 1940, by D. J. and J. N. Knull. Holotype male, allotype and paratypes in writer's collection, paratypes in collection of the U. S. National Museum and The Ohio State University.

This species is close to *C. purpurascens* Schffr. Mr. W. S. Fisher kindly compared a specimen with the type and stated that the latter species has a more strongly convex pronotum which is more deeply, confluently punctured. The clypeus is more deeply, subangularly emarginate in front. The tips of the elytra are deeply emarginate with the teeth strongly produced.

Science In Your Life

It is uncommon to find books dealing with science for the layman which are both accurate and easily readable. Such a combination is presented in the little book "Science in Your Life." Twenty-two brief chapters are contained in its 104 pages. Catchy chapter titles, such as More Power to You, On the Level, More than Meets the Eye, Quick as a Flash and Singing Waves, add to the book's fascination. It is so simply written that anyone with an elementary school education should find it interesting.—*D. C. Rife.*

Science In Your Life, by John Pfeiffer. 104 pp. New York, the Macmillan Co. 1940. 60c.

BOOK NOTICES

Social Problems

This book is offered as a text on what is called the growing rapprochement between the biological and the social sciences. The first 11 chapters would do well as a textbook of genetics. The other 10 chapters treat of intelligence, race problems, population problems, medical problems, insanity, crime, education, and government—all in relation to heredity as the author views that relationship.

Within his own frames of reference, Professor Burlingame is altogether fair, but his frames of reference, and therefore his orientation and his net emphasis, are the familiar ones of those eugenists who believe that the mentally deficient and the dull members of society are, in and of themselves, sources of social evils. Psychologically, this belief is nothing other than "projection," defined as blaming some group of persons different from one's own associates for difficulties which are by no means of that group's making. It may be a very human failing, but it is no less a failing, and one from which the eugenics movement has long suffered. The naive student will see in this book support for the too easy notion that the feebleminded and other deviate groups in our population are *verae causae*, in the sense that if only suitable negative selective measures could be applied to such groups, social matters would automatically be improved.

In so far as genetical science has something important to contribute to the subject, it is that the "tail" of the population's distribution comprising our "dull" and "unadjusted" groups is certainly going to remain with us, even when we succeed in greatly improving our average biological lot by effective eugenic measures. Since the whole problem is obviously a relative rather than an absolute matter, one can expect that, if anything, not fewer but *more* of the relatively dull and unadjusted members of society will be recognized when substantial eugenic progress has been made.

And if the social sciences have anything to say on the problem, it is that the dull and unadjusted are in any case not the causes of social conflicts. Even if it were possible to remove these groups from the population for a generation, we might thereby deprive some eugenists of a bogey of which they are fond, but the operation would leave virtually unaffected the larger social issues which Professor Burlingame has ventured to discuss. The solution of the problem of our deviate groups lies, not in exaggerating the financial costs of these individuals to society as a whole—which costs are, in sober fact, very small—nor in entertaining scapegoatological attitudes towards them, but in facing squarely the need for greatly improving our supervisory and institutional facilities.

This is not to say that eugenic progress is not very much worth working for. It is to say that Professor Burlingame has presented wrong reasons for eugenic measures of any kind; and worse, he does not seem to know what sound and effective eugenic measures would be. In this book, published several years after the American Eugenics Society inaugurated its contemporary program (1935), one looks in vain for any reference to that organization's efforts to set up measures which would have favorable selective effects on the full range of genotypes in the population's distribution.

Much of the material in the latter half of the book centers around differential birth rate statistics. On this, the student would never suspect that Francis Galton, R. A. Fisher, and others have pointed out that the "social promotion of infertility" is a marked phenomenon in any such society as ours. Clearly, persons of higher socio-economic status are frequently of that status as much because of their infertility as by virtue of genetic capabilities. This fact renders dubious most of the argumentation from data on differentials in the birth rate, which data the author would apparently have the student take at face value as indicating dysgenic trends.

Included without criticism are the ideas of Raymond Cattell to the effect that the mean genetic intelligence of such populations as ours and England's may be declining several IQ points per generation. These claims involve the old fallacy that the test-intelligence of children is somehow independent of their home and school

background and may therefore be taken as a perfectly sound measure of genetic variation.

Also included without either criticism or citation of author are the "scare" statistics derived by Caroline Robinson and published by the Journal of Heredity; they are figures to the effect that many persons are dependent on others, and they are stated as if such facts were somehow peculiar to our society! Many parts of the important data assembled by Lorimer and Osburn are presented, but with much less of the care and caution which those authors used in interpreting the same materials in their *Dynamics of Population*. Professor Burlingame's treatment of such sociological problems as arise in connection with Negro and Jewish groups is scarcely felicitous. On the whole, the author's emphases seem to this reviewer to be wide of the mark for leading to significant improvements in either biological or social directions.

Professor Burlingame calls upon social scientists to do something about genetic dangers seen by him. Yet no mention is made of such a reference as Julian Huxley's important Galton Lecture of 1936, in which the classical eugenists were urged to learn the methods as well as the concepts of the sociologists. There is shown in the book little understanding of what modern eugenists and social scientists have been saying and doing for years. It is regrettable that the author's efforts are much more likely to be confusing than enlightening to those for whom the book was written.—*B. Price.*

Heredity and Social Problems, by L. L. Burlingame. xi+369 pp. New York, the McGraw-Hill Book Co. 1940. $3.50.

A New Viewpoint on Eugenics

Eugenics has traveled a rocky road through the years since genetics first gave an impetus to the belief that somehow it might be possible to have more and more children born to those persons who make the most effective response to their environments, and fewer and fewer to those who respond less effectively. Many eugenic proposals have been made on insufficient data, on poorly thought-out premises, or by those who did not have the training and background necessary for the formulation of such policies. Consequently there have been many attacks on eugenic proposals, some of which have included counter-proposals even more radical and unscientific than those they sought to replace.

The author of the present volume approaches the subject sanely, including only such scientific data as are confirmed and weaving his policy into the already accepted ideals and population trends of the American people. He makes it clear that eugenic selection should be encouraged not between socio-economic groups, but within all such groups. Children in all groups are entitled to be born to parents who want them, who will care for them properly, and who will give them good heritage. Such ideals can come about only with community help to all children, involving not only education, but nutrition, medical care, adequate home and recreational environments and many other things.

This book stands out like a beacon light among treatises which are biased, prejudiced or confined to narrow limits. It should be read by all parents, teachers, and especially by those who help to formulate population policies of any sort.—*L. H. S.*

Preface to Eugenics, by Frederick Osborn. xi+312 pp. New York, Harper and Bros. 1940. $3.00.

Elementary Chemistry

The text is designed for a year's course in elementary chemistry. The treatment of descriptive chemistry is well organized and is not overburdened with detailed listings of properties which are not of general interest. The outlines for study, the diagrammatic summaries and review sections are excellent both from the standpoint of the student and the teacher. The illustrations are good but it is unfortunate that the publisher has chosen to place groups of these on individual pages rather than at pertinent points within the body of the text. The chapters on "Valence, Nomenclature, Graphic Formula" and "Chemical Equilibrium" are to be commended.

Since one of the purposes of the book from the student viewpoint is to "enable him to continue in any of the specialized branches of the science" certain omissions in theoretical discussions seem hard to justify. After a lengthy and good discussion of acids and bases from the older viewpoint, a very sketchy treatment of the widely used Brönsted theory is given with the statement that "while the Brönsted theory is broader in scope and invaluable in research, it is of theoretical interest only to students in general chemistry." In the earlier part of the same chapter, in the discussion on ionization, it would seem desirable to have pointed out that the treatment given applies to weak electrolytes and to have made some mention of the newer treatments which give an approach to strong electrolytes. Objection seems justified to the use of "bound" and "free" protons in atomic structure, with neutrons listed only as "additional nuclear units." Finally, the development of the Periodic Law does not take sufficient cognizance of the fact that certain of the objections to the Mendeléef form of the Periodic Table may be at least partially removed by the use of more extended forms.

With the above exceptions the book is very well done. It is only fair to point out that the questions raised concern matters about which considerable controversy has arisen as to the method and place of presentation to the student.

—*J. P. McReynolds.*

Essentials of College Chemistry, by G. H. Whiteford and R. G. Coffin. 534 pp. St. Louis, The C. V. Mosby Co. 1939. $4.00.

Technical Terms and Their Meanings

Certain words or expressions have special meanings and special significance to a person skilled or trained in a branch of knowledge relating to some particular human activity or some particular aspect of nature. Such words or expressions are "technical terms," and are understandable by one not especially versed in the field only through personal explanation or through the medium of a glossary. Glossaries are available for many specialized fields, but there is need for a comprehensive dictionary of broader scope. This need seems adequately met by Chamber's Technical Dictionary. It includes many thousands of terms from the various sciences, from medicine, from engineering, from manufacturing, from construction and from other fields having technical vocabularies. As is only proper, these terms have been defined by specialists engaged in the practice or teaching of their various fields. The list of contributors is an imposing one. The reviewer looked up a random sample of words in the fields with which he is familiar, and found nearly all of them listed, and carefully and accurately defined. The book is one which any teacher or research worker will find invaluable on his desk, and will undoubtedly refer to frequently. An appendix includes the Greek alphabet, a table of chemical elements, the periodic table, tables of igneous and sedimentary rocks, and outlines of the animal and vegetable kingdoms.—*L. H. S.*

Chamber's Technical Dictionary, edited by C. F. Tweney and L. E. C. Hughes. viii+957 pp. Cambridge, at the University Press; in New York, the Macmillan Co. 1940. $5.00.

Insect Transmission of Plant Diseases

The border line subject matter between entomology and plant pathology which deals with insects and their relationship to the transmission of plant diseases is admirably presented in a pioneer textbook entitled "Insect Transmission of Plant Diseases" by J. G. Leach, Professor of Plant Pathology at West Virginia University.

It is apparent that the author possesses fundamental knowledge concerning insect structure, physiology and behavior for he presents the subject matter relating to insects in a very satisfactory manner.

One only needs to hastily scan the contents of the book to be impressed with the magnitude of the field. Careful reading of almost any portion, particularly the chapters on insects and bacterial, fungus and virus diseases, reveals the fact that the author has covered a vast amount of literature and he presents the significant facts in a manner which should be satisfactory to most entomologists and plant

pathologists. He carefully cites the names of all authors whose opinions or findings he quotes.

Each chapter is followed by a list of the most important references. At the end of the book the author includes several interesting tables. Table I lists the more important diseases and the insect vectors of each, while Table II lists all possible vectors and the diseases each may transmit. A glossary of terms used in the literature cited is found at the end of the book.

The reviewer has read the entire book and has profited considerably by so doing. Professor Leach has made a splendid contribution for entomology and plant pathology and is to be congratulated.—*A. Peterson.*

Insect Transmission of Plant Disease, by J. G. Leach, 615 pp., New York, the McGraw-Hill Book Co. 1940. $6.00.

Introduction to Entomology

In this latest revision of Comstock's classic entomology text the only major changes have been in the chapter on the Hymenoptera. The discussions of the superfamilies Ichneumonoidea, Proctotrupoidea, and Chalcidoidea have been revised and extended, and keys to the subfamilies of Ichneumonidae and Chalcididae have been included. There is a new key to the families of Chalastogastra, and a short key to the commoner families of Clistogastra has been added. A great many bibliographic references on the parasitic Hymenoptera have been cited in this chapter, while the principal bibliography, at the end of the book, is unchanged. The text and keys for this new matter was contributed by Dr. Henry K. Townes. These changes will make the book more valuable particularly to those interested in the parasitic Hymenoptera.

There are still a few typographical errors in this edition, particularly in page references, though most of the errors of earlier editions have been corrected. The index has been completely revised. Like the preceding editions, this one is well bound to withstand the hard usage it is likely to get.—*D. J. Borror.*

An Introduction to Entomology, by John Henry Comstock. xix+1064 pp. Ithaca, Comstock Publishing Co. Ninth Edition Revised, 1940. $5.00.

Physics from a New Viewpoint

Smyth and Ufford present an entirely new approach to the teaching of physics in their book, Matter, Motion, and Electricity. That which immediately distinguishes their volume from others is the use throughout of the m.k.s. system of units and the introduction of topics in a sequence quite different from the usual one.

The authors believe that the use of the m.k.s. system of units is a definite step forward. This may indeed be true since it leads to the exclusive use of the practical system of units in electricity, and this is certainly a desirable feature. This reviewer is inclined to feel that what is here gained may be lost elsewhere, but this may be prejudice. Probably only a test of the system can actually decide what are advantages and disadvantages.

Chapter I, which has the caption, Atoms and Molecules, is devoted principally to the atomic and molecular picture of chemical combination. It is followed by a chapter on the motion and sizes of molecules and with the forces that exist between them. The subject of forces and motion is further expanded upon in the subsequent four chapters; the gravitational law of Newton being introduced to clarify the concept of mass and weight.

Subsequent chapters are devoted to the subject of electricity. The use of the m.k.s. system of units facilitates this since this makes unnecessary the reference to the troublesome e.s.u. and e.m.u. system of units. Such subjects as rotational motion and simple harmonic motion are first introduced in these chapters. The subject of rotational motion occurs in the portion devoted to the motion of electrons in a magnetic field and simple harmonic motion is introduced in the section dealing with alternating currents. Whether the introduction of such subjects at points where they are first needed is the most elegant procedure or not is probably debatable, but

it should certainly appeal to the student who is always wondering about what good these things are anyway, when treated in the conventional sequences.

The book is intended for students who have had a thorough course in high school physics and algebra. Use of trigonometry is frequent and incidental references to the notation of differential calculus are made at appropriate points.

—*H. H. Nielsen.*

Matter, Motion and Electricity, by H. D. Smyth and C. W. Ufford. 648+xiii pp. New York, the McGraw-Hill Book Co. 1939. $3.75.

A Science Teachers Handbook

Teachers of chemistry, physics, general science or biology should find this new book of great value. Section I contains eight chapters dealing with philosophy of science teaching, objectives, psychology, methods, laboratory and demonstration, reading, evaluation, and science clubs. Here the authors have presented a quantity of material in relatively short space which makes careful reading essential but well worth while. The approach is a departure from the traditional methods book, for which much credit must be given to the work of the Science Committee of the Commission on Secondary School Curriculum of the Progressive Education Association. Section II comprises a discussion of devices and materials for teaching science, including the psychology of visual aids, the school journey, flat pictures and stereographs, photography, objects, specimens and models, designed materials, the microscope, the telescope, and projection machines. Section III is devoted to a tabular presentation of sources of materials for teaching science, such as flat pictures, models, etc., charts, books, reference books, textbooks and periodicals. Such a book should certainly be a part of every science teacher's library.

—*Paul E. Schaefer.*

Modern Methods and Materials for Teaching Science, by Elwood D. Heiss, Ellsworth S. Obourn and C. Wesley Hoffman. 351 pp. New York, The Macmillan Company. 1940. $2.50.

American Mammals

The lives, habits, and economic relations of North American Mammals are ably presented in a recent book of this title by W. J. Hamilton, Jr., of Cornell. Widely recognized for his field studies of small mammals, the author has incorporated his own knowledge of ecological relationships along with that of others into a comprehensive and authoritative discussion. Beginning with a general discussion of prehistoric mammals in North America and the probable ecological conditions in which they lived, Hamilton thereafter deals with many phases of present day mammalian life.

Especially noteworthy are the chapters on food, reproduction, migrations, populations, distribution, and behavior. Order and family characters are listed in one chapter in only sufficient detail to orient the student to them. Economic relations are presented under the four topics of useful, injurious, game and fur-bearing mammals. The material is written in a readable style, attractive and stimulating to students. Occasionally the reader is led to feel that details have been sacrificed in the attempt to cover the many phases of a very broad subject. However, the situation has been met by continual references to the literature and by placing extensive bibliographical lists at the end of each chapter. The drawings, photographs and charts are numerous and well chosen. Undoubtedly, Professor Hamilton has made a noteworthy contribution to North American Mammalogy, in bringing together in one volume a digest of our present knowledge of this broad subject, so widely scattered in the literature. His book deserves a place in the library of every student of Mammology.—*John W. Price.*

American Mammals, by W. J. Hamilton, Jr., xii+434 pp. New York, the McGraw-Hill Book Co. 1939. $3.75.

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